MEMORY RECONSOLIDATION IN TRAUMA-LIKE MEMORY

by

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Abstract

Individuals might meet difficulties in updating and integrating traumatic memories with existing autobiographical memories, which could lead to posttraumatic stress disorder. Eye Movement Desensitisation and Reprocessing (EMDR) therapy putatively facilitates adaptive memory updating and integration. While eye movement is critical to the therapeutic benefit of EMDR, their mechanism of action remains unclear. We applied video trauma memory with counterconditioning to test the effect of eye movement in EMDR directly. We also explored the importance of internet-based interventions and culture differences in updating trauma-like memories. In experiment 1, we recruited 69 undergraduates from the University of Birmingham. Participants were exposed to distressing film clips and counterconditioning took place a day later. Subjective distress was recorded daily for one week, and declarative memory for the trauma video was also tested on the final day. In experiment 2, we recruited 35 healthy participants from the Southwest University in China and 24 healthy participants from the University of Birmingham; 26 participants completed their experiments in person, and 33 participants completed their experiments online. The experimental procedures were the same as the ones in experiment 1. The results in experiment 1 indicated that eye movement combined with counterconditioning had the lowest IES-R scores among all the groups, but these results were not repeated in declarative memory tasks. In experiment 2, we replicated the effect (eye movement + war + humour) in different cultures and types. However, we only compared the difference between fully memory reconsolidation condition (eye movement + counterconditioning) and control group. Therefore, we were unable to conclude that eye movement can enhance memory reconsolidation, but counterconditioning might play an important role in memory reconsolidation which is a universal phenomenon.

Acknowledgement

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General Introduction

Post-Traumatic Stress Disorder

Posttraumatic stress disorder may follow emotional trauma in around 10%, and is characterised by the recurrence of intrusive memories, avoidance, and hyperarousal according to Diagnostic and Statistical Manual of Mental Disorder (American Psychiatric Association, 2013; McManus et al, 2016). Some serious consequences of PTSD are changes in thinking, emotional expression, value orientation, life beliefs, and perceptions of life value changes (Kekelidze and Portnova, 2011). Moreover, it affects interpersonal communication (e.g. Work, life) and is often associated with other mental disorders (such as substance use, depression, anxiety disorder), which can decrease life quality (Ginzburg et al., 2010).

Specifically, intrusive memories are very common in the initial aftermath of trauma, and they consist of sensory fragments of the trauma (Ehlers et al, 2002). Some researchers further observed that intrusive memories are accompanied with “nowness”. For example, individuals can feel the sensations that are experienced in the present rather than as a memory from the past, and these sensations accompany the intrusive memory as the same as the original time (Hackmann et al, 2004). Several explanations have been proposed for intrusive memory triggers and the sense of "nowness" that accompany them. From Michael and his colleagues’ work in 2005, they proposed that PTSD sufferers would experience poor integration of elements in traumatic experience with each other, and with previous context and information. As a result, individuals might have difficulty in accessing contextual information, which might prevent the traumatic memory from being updated. A good example can be failure to access the context about being safe after the threatening event during an intrusion of re-experience or witness the threatening event again, will induce a sense of current threat.

Moreover, individuals who suffer from persistent trauma will lead to a serious sense of current threat, which might partly come from the nature of traumatic memory itself (Dunmore et al, 2001). Some researchers explained that traumatic memories are poorly expanded in detail and integrated with existing autobiographical memories. Therefore, PTSD sufferers might not internally recall the traumatic memory, whilst experiencing unintentional triggering of symptoms and cues related to trauma. Furthermore, this might hamper the incorporation of information which might deny negative appraisals (Dunmore et al, 2001).

In summary, it can be noticed that most of the symptoms start with memory persistence. Therefore, exploring long-lasting memories and updating / integrating intrusive memory can be essential in trauma-related problems.

Eye Movement Desensitisation and Reprocessing (EMDR)

Eye Movement Desensitisation and Reprocessing (EMDR) is a therapy that is widely used in memory-related disorders and effective in early intervention (Shapiro, 2012). It was proposed as a trauma-focused treatment in 1987, where Shapiro observed that eye movement can calm negative emotions (Shapiro, 2012). In this therapy, a psychotherapist asks the patient to focus on a traumatic memory image while simultaneously attending to an alternating stimulus for brief eye movements (right-left) sets. Then, the psychotherapist asks the patient to establish a positive image to update the traumatic memory (Shapiro, 2012). In addition, EMDR is considered as evidence-based practice in the United Kingdom by the National Institute for Clinical Excellence (2005), in America by the American Psychiatric Association (2004), in Australia by the Australian Centre for Posttraumatic Mental Health (2007), and in the Netherlands by the Dutch National Steering Committee for Guidelines for Mental Health Care (2003).

Furthermore, a number of previous works have found that EMDR has remarkable and long-lasting effects for treating PTSD (Seidler & Wagner, 2006; Chen et al, 2012; Chen et al, 2015). In Chen and her colleagues' meta-analysis (2012) about randomised controlled trials in EMDR from 1991 to 2013, they reported that EMDR not only reduced PTSD symptoms, but also reduced anxiety and subjective distress when coping with the trauma. Moreover, there are also several meta-analyses comparing the efficiency between EMDR and Trauma-focused cognitive behavioural therapy (CBT) (which is a helpful and appropriate choice of individuals). In addition, predictive processing modelling has expan Chen and her colleagues in 2015 found that EMDR may be more effective in decreasing the severity of intrusion and arousal symptoms.

Despite demonstrated efficacy, little is known about the mechanisms of EMDR's therapeutic action. First, it is not clear how traumatic memories are processed and updated in this therapy. There are several models to explain the mechanisms of action underlying EMDR. For example, the Adaptive Information Processing Model (AIP) has guided the treatment of PTSD. It hypotheses that "dysfunctional stored memory" served as trauma, and "there is a system inherent in all of us that is physiologically geared to process information to a state of mental

health… by means of this system, negative emotions are relieved, and learning takes place, is appropriately integrated, and is available for future use" (Shapiro, 2018). In addition, predictive processing modelling expands them in detail from a neurobiological perspective (Chamberlin et al, 2019). In this model, the author hypotheses that the brain would reexperience the trauma during EMDR, and then predict what will come next according to the old memory. Then, saccadic eye movements guided by the therapist force the individual doing multi-modal sampling of current sensation to predict what comes next. However, old memory would not happen, and this prediction error registers in the brain as Mismatch Negativity in multiple regions. Subsequent sampling is invoked to generate new predictions and individuals would minimize the prediction error with updating memory in the end.

Second, we also do not understand how eye movement affects the whole process. EMDR has been described as a complex procedure with mindfulness, cognitive restructuring, and other exposure related to trauma. Lee and Cuijpers in 2013 proposed that non-clinical environments would more likely measure the direct value of eye movement and intrusive memory rather than additional value of it as other elements are absent. They found that the additional value of eye movements in EMDR treatment averaged a medium effect size advantage for eye movements over no eye movement. For further explanations, some researchers found eye movement can decrease the memory vividness and emotionality, but it is not consistent with data (Kavanagh et al., 2001). Therefore, we will explore the effectiveness of the therapy and the function of eye movement from memory reconsolidation perspectives in a non-clinical condition.

Memory reconsolidation and destabilization

Memory can be updated in certain conditions and then be reconsolidated. Extensive data indicates that memories may be unstable upon retrieving, and memory is more dynamic than previously thought. Memory can be updated by inducing prediction error while old memory is unstable and further being stable again, and this process called memory reconsolidation (Alberini & LeDoux, 2013; Schwabe, Nader & Pruessner, 2014). Indeed, memory can be reconsolidated by inducing new learning to take place while old memory is reactivated (Sevenster,Beckers, & Kindt, 2013).

Then, memory reconsolidation can be useful for processing memory persistence in trauma-related issues. Early, it allows individuals to update memory flexibly, and thus adapt to the changing environment. Later, it offers great opportunities to treat fear memory by altering,

enhancing, and affecting memory (Schwabe, Nader & Pruessner, 2014). As a result, memory reconsolidation can be applied to the treatment of post-traumatic stress disorder in the early stage by modifying patients' emotional memories (trauma), and it becomes less likely to over-consolidate. Due to the widely potential applications, a large number of researchers have been actively working on improving the successful rate of memory reconsolidation over the past decade and have accumulated rich knowledge about it (Auber et al,2013).

A number of observations witnessed the process of reconsolidation in humans (Finnie & Nader, 2012). Moreover, some researchers have taken interventions, such as injecting beta-adrenergic receptor blocker before reactivation or introducing new learning after reactivation to disrupt old memory (Schwabe, Nader& Pruessner, 2014). However, some experiments have failed to observe reconsolidation-like effects, which let researchers explore the potential key factors to facilitate memory reconsolidation. Despite the experiment materials and participants pool, researchers notice that some factors limit or prevent the reconsolidate inducing, also known as boundary conditions (Wideman, Jardine & Winters, 2018).

Time can be crucial in memory reconsolidation. To achieve memory reconsolidation, the new learning needs to occur within a limited period, when the old memory is unstable (Piñeyro et al, 2014; Schiller et al,2010; Tay et al, 2019). This period is termed as "reconsolidation window" (Nader & Hardt, 2009), whose existence was reviewed by Lee, Nader, and Schiller in 2017. During this period, behaviour reconsolidating (extinction, counterconditioning, and interference) would interfere with the target memory system during the destabilisation period and form an adaptive memory system by new information and learning.

Specifically, generating a prediction error (which is a mismatch that occurs when there is a difference between what people expect and what actually happened) can be useful to update memory better (Lee, Nader & Schiller, 2017). In addition, Counterconditioning can be an effective method as it can maximise the prediction error and prevent renewal effect (Das, Lawn & Kamboj, 2015). For instance, Researchers induced aversive counterconditioning after reactive maladaptive reward memory (e.g. heavy drinking Memories), and they found it leads to relapse prevention and ceases to evoke craving (Das, Lawn & Kamboj, 2015; Goltseker, Bolotin & Barak, 2017;2016). A negative example can be Kindt and Soeter in 2013, which failed to prevent the return of fear memory by using the fear conditioning paradigm. In this experiment, they used only about 10 CS+ where one colour square paired with a mild electric

shock on the wrist and 11 CS- where another colour square without pairing electric shock. As a result, participants were not confident enough to distinguish between CS+ and CS- through limited trials and similar features.

However, memory reconsolidation is a complex process and it varies in individuals. Thus, we will identify what components are important in the memory reconsolidation process, and whether the outcomes of the process can vary when coming to a different experimental environment (online/in person) and country.

Overall, we aimed to examine memory destabilisation and updating as a possible mechanism underlying the effects of EMDR on trauma-like memory.

Experiment 1

Introduction

To reconsolidate memory, destabilizing it first is necessary. From animal study, researchers found that memory destabilization before extinction can attenuate spontaneous recovery and retard reacquisition of conditioned fear (Piñeyro et al, 2014). There are also several human studies demonstrating the importance of reactivation-induced destabilization in facilitating memory change (Hupbach et al., 2007; Forcato, Rodríguez, Pedreira, & Maldonado, 2010). In these studies, researchers found the correct recall rates from a new learning list significantly decreased when a reminder of the old learning list was present before new learning. However, there are some experiments that failed to facilitate memory reconsolidation (Sevenster, Beckers & Kindt, 2012; Kindt & Soeter, 2013). In their study, they reactivated the fear memory in unreinforced condition with only one trial, which might not be enough for memory destabilization. Therefore, it is important to facilitate memory destabilization with some necessary methods.

For example, Almeida-Corrêa and Amaral (2014) suggested that memory destabilization is procedurally the same as short extinction and the degree of similarity between the original experience and the new one would lead to different results (reconsolidation or extinction). They proposed that reconsolidation and extinction share the same plasticity system involved in the labilization of memory. Moreover, From the work of Boukezzi and her colleagues in 2017, participants who received alternating bilateral stimulations (which is auditory stimulation) had

less fear expectation during the fear extinction phase. Therefore, it is reasonable to predict that eye movement can also enhance memory destabilization.

There are two experimental paradigms widely used to study trauma-like memory reconsolidation. The traumatic movie paradigm introduces new trauma-like memory by watching some traumatic video clips (i.e. war-related, sexual abuse, or car accident videos) (James et al, 2016). In this research, the traumatic movie paradigm was used for the following reasons. First, introducing a new memory can ensure that participants have the same emotional memory, while participants' autobiographical memory can be diverse and subjective. As a result, the whole process can be more standard and replicable, thereby reducing the difference between. Second, memory reconsolidation is easier to succeed when memory to be reactivated is newer (Kida, 2020). Therefore, introducing a new trauma-like memory can increase the success rate of memory reconsolidation and avoid the ceiling effect. Moreover, we added counterconditioning (participants would watch humour video clips after war video clips) to facilitate memory reconsolidation and test whether eye movement can enhance destabilization.

Even though eye movement may facilitate memory destabilization, eye movement is also considered as a cognitive distraction in memory retrieval, which might facilitate memory reconsolidation directly. One of the most influential theories in this area is working memory theory. In this theory, it believes that a second task (such as eye movement) will tax limited working memory resources, and therefore dual tasks can blur memory (Andrade, Kavanagh & Baddeley, 1997). Thus, it is worth investigating whether eye movement can impair recall and therefore facilitate memory reconsolidation.

All the above considered, eye movement was a cognitive distraction task. counterconditioning will be combined with the traumatic film paradigm, and the theme of the video clip for counterconditioning would be the same as the traumatic video.

Therefore, the first hypothesis of this experiment is that counterconditioning with enhanced destabilization will impair reconsolidation in trauma-like memory. When referring to eye movement, it can be a cognitive distraction which can impair reconsolidation directly. Thus, we hypothesized that eye movement with counterconditioning has the greatest reduction in trauma-like symptoms. However, there might be no significant difference between eye

movement + counterconditioning and counterconditioning itself depending on the degree of reactivation in memory reconsolidation.

Method

Participants

79 undergraduate students were recruited from research participants scheme in the University of Birmingham for course credits, but three of them dropped this study due to the university lockdown (age from eighteen to twenty-four; twenty-one males and fifty five females). Participants who have anxiety disorder or post-traumatic stress disorder were excluded. Moreover, participants who got 36 or more in the anxiety sensitivity index (Peterson & Heilbronner, 1987) were screened out from this study due to the possible risk when watching the traumatic video.

Ethics

This study has been approved by University of Birmingham STEM Ethical Review Committee (ERN_19-1642). Participants read the information sheet about the process and potential risks of this experiment and signed the consent form.

Design

This experiment is a three-day protocol which constituted four interventions (group one: eye movement + traumatic video + humour video; group two: traumatic video + humour video; group three: eye movement + traumatic video; group four: eye movement + humour video) in eight days. There was trauma film encoding on the first day, the four interventions on the second day, and the descriptive memory task on the eighth day. There were 18 participants in the first group, 18 participants in the second group, 17 participants in the third group, 17 participants in the fourth group. For the reactivation on the second day, we aim to reflect the eye movement stage in EMDR and combine it with the memory reconsolidation process. Therefore, participants were first exposed to an auditory reminder (the background sound from the traumatic video) when they performed eye movements, which was similar to how the therapist asks patients questions while they are performing eye movements (Davidson & Parker, 2001). After that, participants re-watched the war video clips that played on the first day.

First, we needed to reflect that within EMDR therapy, the therapist asks questions to facilitate the recall of the traumatic memory while the patient is performing eye movements (Davidson & Parker, 2001). Therefore, participants were exposed to an auditory reminder (the background sound from the traumatic video) when they performed eye movements.

Measurement

For the subjective measurements in this experiment, the researcher used subjective distress rating to rate their subjective distress from 0 (totally relaxed) to 100 (the most distress moment I ever had), Impact Event Scale-Revision (IES-R) (Weiss, Marmar, 1997), and declarative memory task to test participants' recall memory performance and daily feelings about the traumatic video clip. Moreover, the primary measurement focused on total score and intrusive subscale in IES-R. Therefore, the primary outcome of this research would be similar to the traumatic film paradigm. For objective measurements, this study, the researcher used skin conductance response sensors called eSense Skin Conductance System (Mindfield Biosystems, Inc., Berlin, Germany). Data was acquired at 10 Hz and exported via CSV files over email in each Skin Conductance Response (SCR) measurement. This e-sense skin conductance system was compared with traditional SCR systems in previous studies, and its performance was as effective and accurate as performance in traditional SCR systems (Hinrichs et al., 2017). Previous study also demonstrated the eSense Skin Conductance System as an accurate tool for measuring participants' stress in different tasks (Liapis et al, 2015).

Material and procedures

Participants with interventions

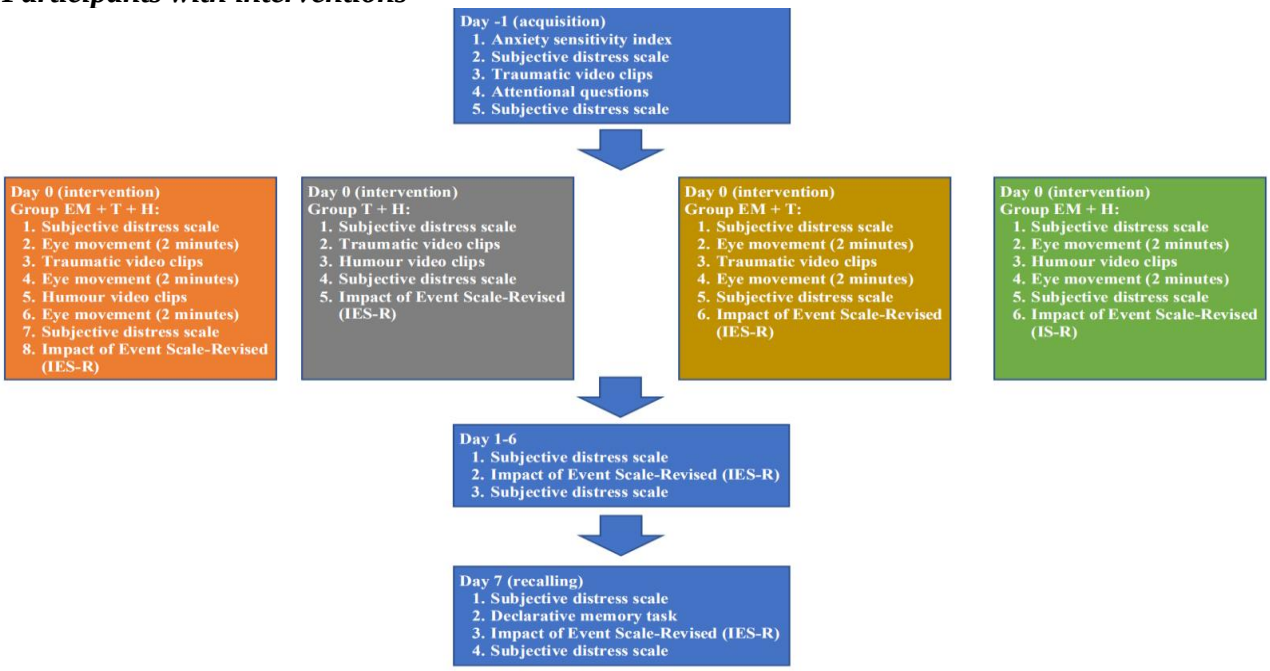

Figure 1. *experiment processing from day-1 to day 7.*

On day -1 (acquisition phase), participants were requested to fill in the anxiety sensitivity index and subjective distress scale rating from 0 to 100 (0 = not stress at all, 50 = moderate of distress but can continue to function, 100 = highest distress you even have) in the beginning. Then, participants who passed the anxiety sensitivity index watched ten-minute war video clips from *Hacksaw Ridge* online. After that, they needed to answer an attentional question (How many red letters A do you see in this video?) and rated the subjective distress after watching.

On day 0 (reactivation phase), participants who passed the attentional question on day -1 were invited to attend session 2 in a study cubicle in University of Birmingham. Participants were tested individually in front of a computer screen. Then, the researcher ran the program written in Python to start the intervention. Participants in group one, three and four followed a red dot that moved horizontally on the computer screen at 1.2 Hz frequency for two minutes, while the background sound from the war video clip was played at maximum volume (eye movement phase). Participants in group two started to watch the traumatic video clip from the beginning. After that, participants in group two watched humour videos from *Welcome to Dongmakgol*, *Mr. Bean (Yes! Sir)*, and *Best army fail compilation* from YouTube. Meanwhile, participants in group one, three and four watched either a traumatic movie (group one and two) or humour video (group four). Then, participants in group one, three and four repeated eye movement again. Finally, participants in group two, three and four finished interventions but participants in group one watched humour video clips and then did eye movement for two minutes again in the final phase. After the intervention, they were asked to fill in the IES-R and subjective distress score again. From day 1 to day 6, participants filled in IES-R and subjective distress ratings online every day to record their reactions and feelings about the traumatic video clip. On day 7 (a week later after reactivation), participants returned to the same study cubic to complete the last session. Then, participants recalled the traumatic video clip by declarative memory task with some guidance questions (i.e. Can you recall what happened in that video? What was mainly talked about? Please give as many details as you can.). In the end, they reported IES-R one more time before debriefing and finishing this experiment.

Data transformation and statistical analysis

Impact Event Scale-revised (IES-R)

All scores were first calculated and analysed in the original format. Then, we will individually check the score on day 0 as a baseline and compare all scores from day 1 to day 7.

Subjective distress score

The scores before intervention/questionnaire were subtracted from the scores after intervention/questionnaire individually for every day. In this experiment, when participants'

distress scores can be various in the beginning, we asked participants subjective distress scores before intervention to establish an initial measurement. After they finished the videos or intervention, we wanted to know the changes of participants (McCabe, 2015). Therefore, we used the difference between before and after intervention as participants' daily subjective distress (original score). Moreover, we will set the score on day 0 as baseline and compare all scores from day 1 to day 7.

Skin conductance response

Skin conductance response for each participant was calculated by subtracting the mean of a 30 s baseline period from later intervention with mean centring to account for the participants variance in excitability. Then, a low pass filter (0.5 Hz) filtered the noise and square root transformation was applied to the dataset prior to analysis (Braithwaite et al, 2013). SCR was analysed by means of a mixed analysis of variance (ANOVA) for repeated measures with condition (group one vs group two vs group three vs group four) as between-subjects factor and eye movement/war/humour/recalling period were analysed separately. Planned comparisons were performed for each condition separately.

Declarative memory tasks

In this task, we asked participants to recall the war video and scenarios that includes when, where, and how would be counted as one detail. We also used poisson distribution into ANOVA accordingly because this is count data (James et al, 2016).

Statistic tools

We used Car packages in R to run Shapiro-Wilk test (normality), Levene's test (equality of variances), one-way ANOVA, two-way mixed ANOVA. JASP was used to calculate Bayesian one-way and two-way mixed ANOVA, and the default Cauchy prior is centred on zero, as the standard practice in Bayesian statistics (Marsman & Wagenmakers, 2017). To address heteroscedasticity, we applied Heteroscedastic Corrected Covariance Matrix (hccm) to one-way ANOVA when Levene's test is less than 0.05(Pek, Wong & Wong, 2018). To account for any departures from sphericity, we applied Huynh-Feldt-corrected estimates if $\sum \geq 0.75$, and Greenhouse-Geisser correction if $\sum < 0.75$ applied in ANOVA analysis (Girden, 1992). Criterion for significance was set at 0.05 and partial eta squared ($\eta 2$) was used as effect size. For multiple comparisons, we used the "Tukey" method which was designed for unequal numbers in participant groups (McHugh, 2011). The percentage of missing data is 9.16%. Then, the missing data were filled Fully Conditional Specification (FCS) implemented by Generates Multivariate Imputations by Chained Equations (MICE), which is implemented by the "mice" package in R (van Buuren & Groothuis-Oudshoorn, 2011).

Result

In this study, we first used one-way ANOVA to analyse the baseline (which are the scores on day 0). Then, we used two-way mixed ANOVA with the imputation dataset to investigate whether there is a group difference in IES-R and subjective distress. In addition, this study would test the distribution and Homoscedasticity of the dataset in each subscale (subjective distress, total score, intrusive, avoidance, hyperarousal from IES-R). As a result, we can verify the importance of data distribution in statistics.

IES-R (original score)

Day 1 to day 7

From figure 2, it is noticeable that the spread of data in total scores, intrusive and avoidance scores are greater while hyperarousal is smaller. From table 1 combined with descriptive data, it is clear that there was a significant difference in avoidance (F (3,65) =3.855, η^2=0.11, $sig._{avoidance}$ =0.048). From the Tukey method to test the pairwise difference
and the group difference was contributed mostly from EM + war+ humour and EM + war (sig. =0.03). EM + war+ humour has a significantly lower score than EM + war.

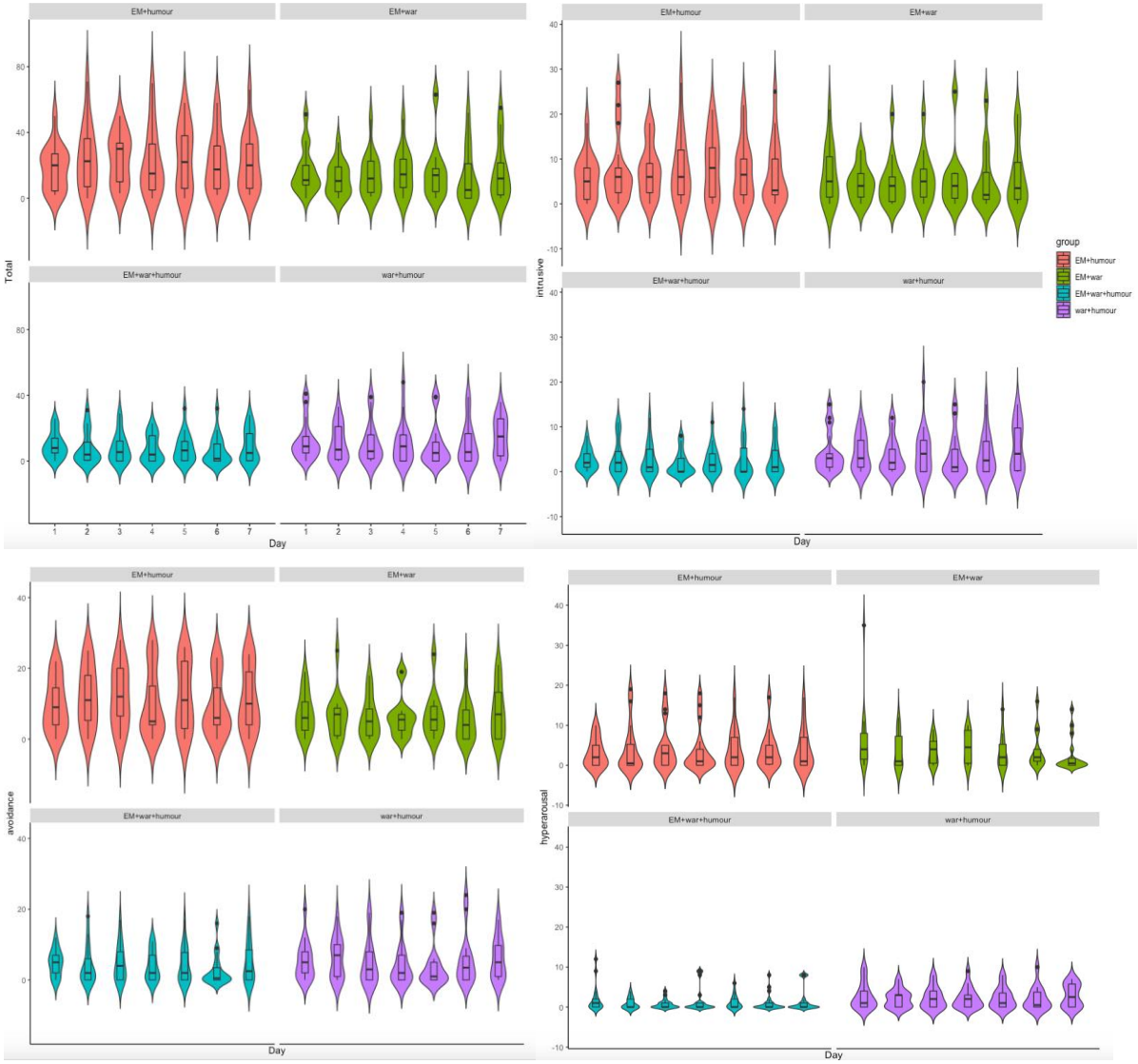

Figure 2. *Total, Intrusive, Avoidance, Hyperarousal score of IES-R from day 1 to day 7.*

Note. EM+ war+ humour is group one: eye movement + traumatic video + humour video; war + humour is group two: traumatic video + humour video; EM + war is group three: eye movement + traumatic video; EM + humour is group four: EM + humour video.

Table 1

two-way mixed ANOVA for IES-R score in total, intrusive, avoidance, hyperarousal division from day 1 to day 7.

	Multivariate test		Mauchly's test		Within-subject effect				Between-subject effect (with effect size)	
					day		Day*group		group	
	original	imputation	original	imputation	original	imputation	original	imputation	original	imputation
total	0.481	0.000*	0.000*	0.000*	0.138	0.402	0.071	0.518	0.022* (0.256)	0.124 (0.08)
intrusive	0.727	0.112	0.000*	0.000*	0.579	0.695	0.388	0.833	0.057 (0.27)	0.12 (0.09)
avoidance	0.612	0.004	0.001*	0.000*	0.096	0.561	0.076	0.419	0.020* (0.28)	0.048* (0.11)
hyperarousal	0.120	0.203	0.000*	0.000*	0.081	0.167	0.060	0.317	0.020* (0.054)	0.456 (0.038)

Note. *p < 0.05.

Table 2

Bayesian two-way mixed ANOVA for IES-R in total, intrusive, avoidance, hyperarousal division from day 1 to day 7

	Effects	P(incl)	P(incl|data)	BF. incl
Total	group	0.400	0.731	2.987
Avoidance	group	0.400	0.705	2.758
Intrusive	group	0.400	0.638	1.770
Hyperarousal	group	0.400	0.502	1.010
Total	day	0.400	0.033	0.035
Avoidance	day	0.400	0.057	0.063
Intrusive	day	0.400	0.016	0.016
Hyperarousal	day	0.400	0.015	0.015
Total	day*group	0.200	0.989	575.367
Avoidance	day*group	0.200	0.038	0.819
Intrusive	day*group	0.200	0.008	0.095

Hyperarousal	day*group	0.200	0.005	0.077

Short-term effect after reactivation (scores in day 0)

From figure 3, it is clear to see there are no noticeable differences between groups in different scores. There are also no significant differences found according to One-way ANOVA (modified by hccm) (total: F (3,65) =2.978, η^2=0.04, sig. =0.089 ;avoidance: F (3,65) =2.825, η^2=0.04, sig. =0.097 ; intrusive: F (3,65) =3.1.465, η^2=0.02, sig. =0.23; Hyperarousal: F (3,65) =0.172, η^2=0.00, sig. =0.679). From the result of IES-R original score, we found that there are some differences in IES-R especially avoidance. However, there is no difference on day 0 after post-intervention in a short period, which might be due to individual difference or time limited. Then, it is interesting to consider the score on day 0 as a baseline and compare the scores from day 1 to day 7 to evaluate the changes in symptoms in a relatively long term.

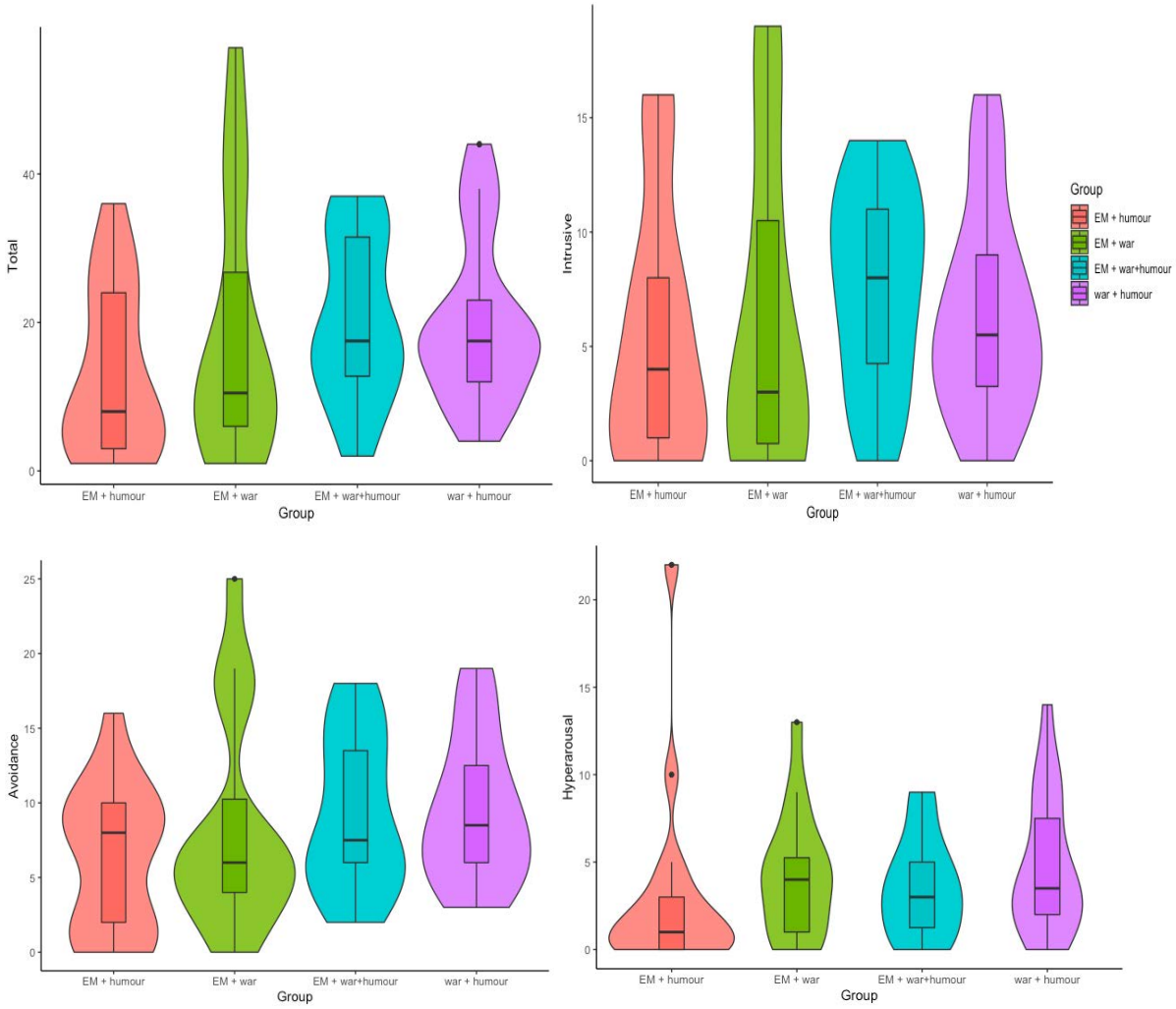

Figure 3. *IES on day 0 for each group with violin plots with box plots.*

Note. All the scores were scores after test/questionnaires subtract from before test/ questionnaires. EM+ war+ humour is group one: eye movement + traumatic video + humour video; war + humour is group two: traumatic video + humour video; EM+ war is group three: eye movement+ traumatic video; EM + humour is group four: eye movement+ humour video.

IES-R (scores from day 1 to day 7 subtracted by day 0)

As expected from the previous hypothesis that there would be changes from baseline, it is worth exploring the difference from baseline between groups. Here, we used the score on day 0 subtract scores from day 1 to day 7. In this case, a higher score in this section means participants decreased more in IES-R scores. From Figure 4, it can be observed that group one (EM + war + humour) decreased mostly since day 1. These differences were confirmed by two-way mixed ANOVA when group different were found in total ($F(3,65) = 3.255$, $\eta^2 = 0.218$, $sig._{total} = 0.000$), intrusive($F(3,65) = 3.255$, $\eta^2 = 0.178$, $sig._{intrusive} = 0.005$), avoidance($F(3,65) = 4.625$, $\eta^2 = 0.229$, $sig._{avoidance} = 0.002$). For multiple comparison, it was found that group one (EM + war+ humour) was significantly different from group three (EM + war) in total difference, avoidance difference, and intrusive difference ($sig._{total} = 0.000$, $sig._{avodiance} = 0.007$, $sig._{intrusive} = 0.006$). Moreover, Group four (EM + humour) decreased significantly less than group one (EM + war+ humour) in total score ($sig._{total} = 0.02$).

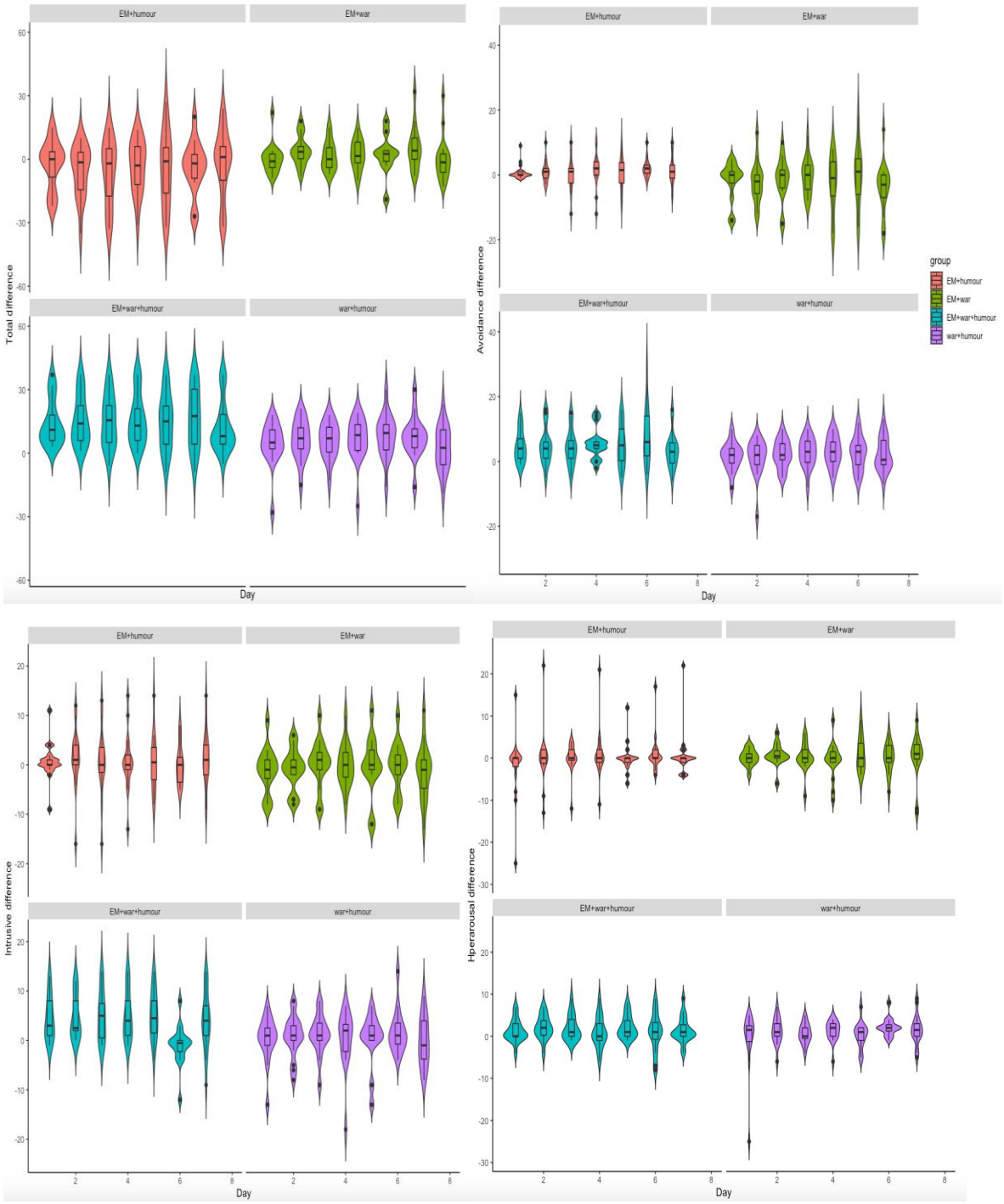

Figure 4. *Total, Avoidance, Intrusive, Hyperarousal score of IES-R from day 1 to day 7 subtracted from day 0.*

Note. The group representation is the same as figure 1. Difference means the total scores from day 1 to day 7 which subtracted from day 0.

Table 3

two-way mixed ANOVA for IES-R score in total, intrusive, avoidance, hyperarousal division that subtracted from day 0.

	Multivariate test		Mauchly's test		Within-subject effect				Between-subject effect (with effect size)	
					day		Day*group		group	
	original	imputation	original	imputation	original	imputation	original	imputation	original	imputation
Difference_T	0.674	0.382	0.000*	0.000*	0.138	0.502	0.071	0.781	0.022* (0.27)	0.000** (0.218)
Difference_H	0.350	0.290	0.000*	0.000*	0.180	0.089	0.364	0.380	0.758 (0.04)	0.593 (0.026)
Difference_I	0.182	0.068	0.000*	0.000*	0.794	0.684	0.062	0.140	0.013* (0.29)	0.005** (0.178)
Difference_A	0.471	0.010	0.022*	0.023*	0.081	0.352	0.061	0.292	0.002* (0.38)	0.002* (0.229)

Note. The missing data processing is the same as table 1. Difference_T means total scores that subtracted from day 0. Difference_H means hyperarousal scores that subtracted from day 0. Difference_I mean intrusive scores that subtracted from day 0. Difference_A means avoidance scores that subtracted from day 0. *p < 0.05.

Table 4

Bayesian two-way mixed ANOVA for IES-R score in total, intrusive, avoidance, hyperarousal division that subtracted from day 0.

	Effects	P(incl)	P(incl|data)	BF. incl
Difference_T	group	0.400	0.936	16.869*
Difference_A	group	0.400	0.899	14.261*
Difference_I	group	0.400	0.775	4.755
Difference_H	group	0.400	0.225	0.291
Difference_T	day	0.400	0.020	0.021
Difference_A	day	0.400	0.063	0.070
Difference_I	day	0.400	0.018	0.019
Difference_H	day	0.400	0.015	0.015
Difference_T	day*group	0.200	0.005	0.287
Difference_A	day*group	0.200	0.038	0.638
Difference_I	day*group	0.200	0.061	4.190

Difference_H	day*group	0.200	0.002	0.074

Subjective distress score

Day 1 to day 7

From Figure 5, it is clear that there was no difference for each group from day 1 to day 7. Moreover, this trend also corresponded to the result from two-way mixed ANOVA, when there was no significant difference among groups and no day difference within each group (Group: F (3,65) =0.991, η^2=0.09, sig. =0.713; day: F (6,390) =0.242, η^2=0.02, sig. =0.918).

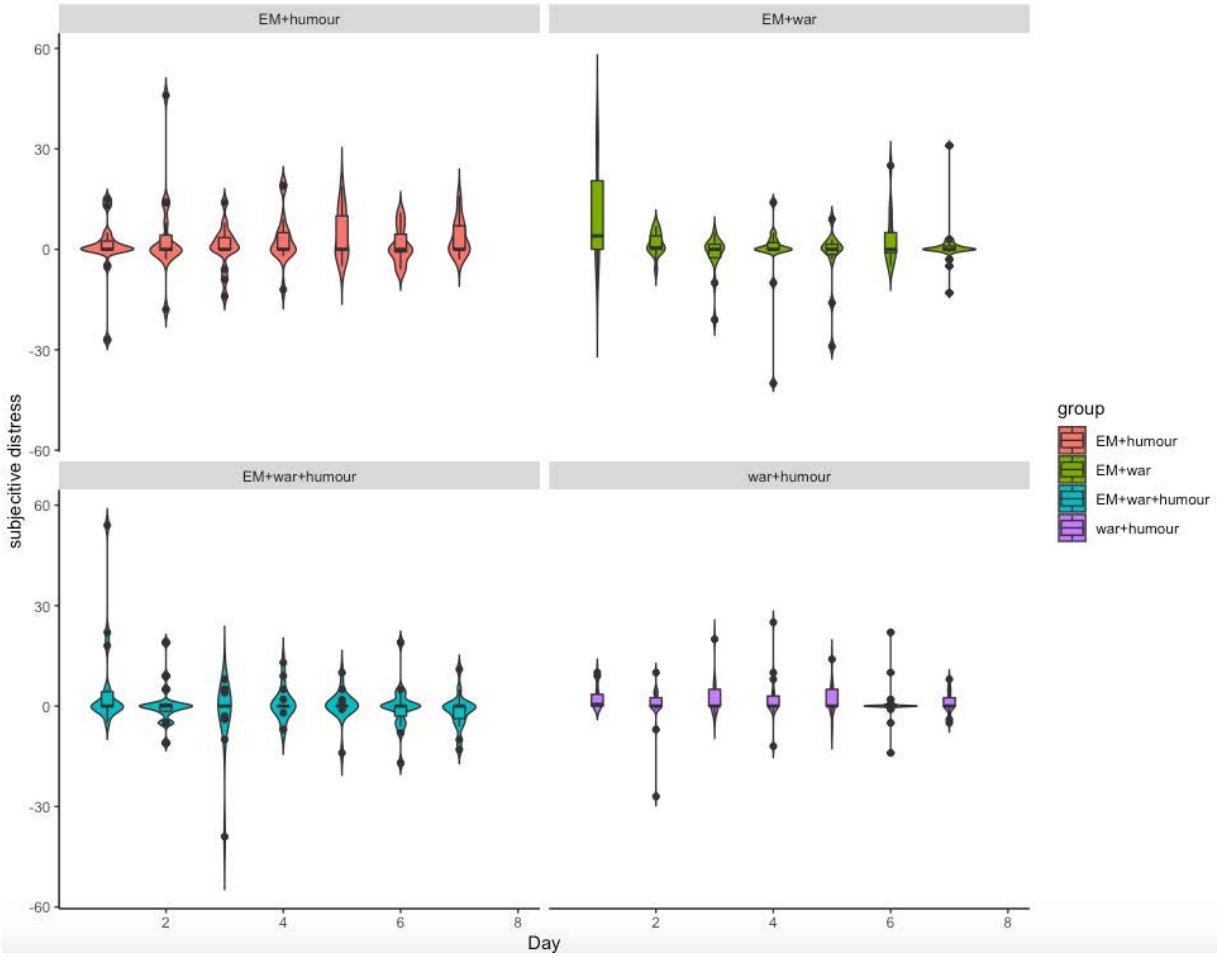

Figure 5. *the original difference of subjective distress score before and after intervention from day 1to day 7 for each group with violin plots with box plots.*

Note. All the scores were scores after test/questionnaires subtract from before test/ questionnaires. EM+ war+ humour is group one: eye movement + traumatic video + humour video; war + humour is group two: traumatic video + humour video; EM+ war is group three: eye movement+ traumatic video; EM + humour is group four: eye movement+ humour video.

Short-term effect after reactivation (scores in day 0)

From figure 6, we can notice that the EM+ humour group changed least among all groups. However, there is no significant difference among all groups according to One-way ANOVA and multiple comparisons (F (3,65) =2.360, η^2=0.03, sig. =0.129).

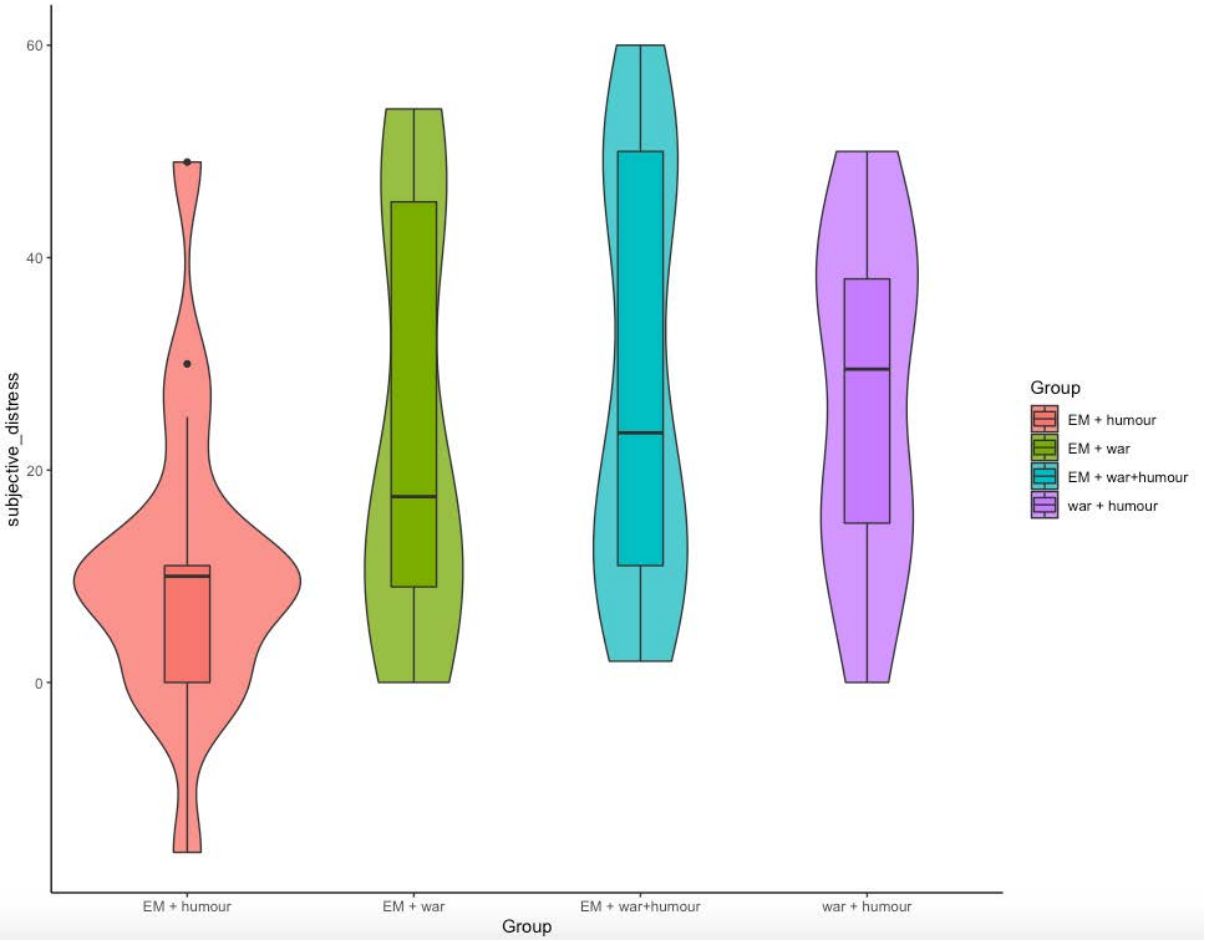

Figure 6. *the difference of subjective distress score before and after intervention on day 0 for each group with violin plots with box plots.*

Note. All the scores were scores after test/questionnaires subtract from before test/ questionnaires. EM+ war+ humour is group one: eye movement + traumatic video + humour video; war + humour is group two: traumatic video + humour video; EM+ war is group three: eye movement+ traumatic video; EM + humour is group four: eye movement+ humour video.

Declarative memory task about war video

There is significant difference among all groups according to One-way ANOVA and multiple comparisons (F (3,65) =9.348, η^2=0.11, sig. =0.025), and it mostly contribute by the difference between group two (war + humour) and group four (EM + humour) (sig.= 0.017).

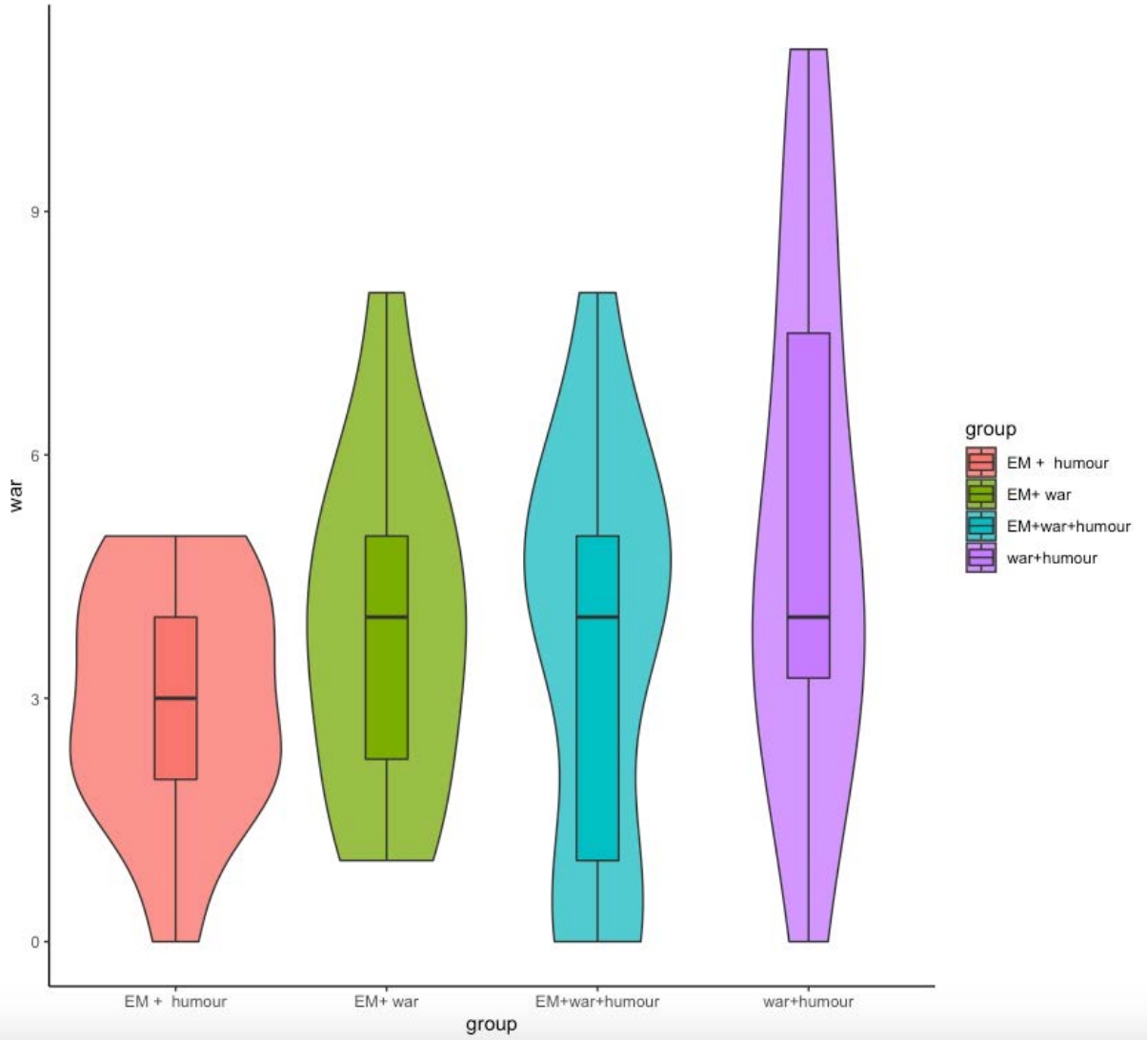

Figure 7. *the difference of subjective distress score before and after intervention in day 0 for each group with violin plots with box plots.*

Note. All the scores were scores after test/questionnaires subtract from before test/ questionnaires. EM+ war+ humour is group one: eye movement + traumatic video + humour video; war + humour is group two: traumatic video + humour video; EM+ war is group three: eye movement+ traumatic video; EM + humour is group four: eye movement+ humour video.

Skin conductance level

From skin conductance level, it is clear to see that there was no difference between groups during the eye movement period and recalling period. When observing the patterns in eye movement period in all groups, there was a huge increase in conductance Level (SCL) during the first 30 seconds and then rapid decrease in the rest of eye movements periods (eye movement periods before and after video clips). Furthermore, paired samples t test was done to compare SCL of participants between the beginning and the end of the period. It confirmed

that SCL in the beginning of the period was significantly higher than the end of the period (p=0.003). From one-way ANOVA, there were significant differences among groups in the war period (F (2,40) = 3.902, sig. = 0.028, η2=0.15) and humour period (F (2,40) =7.555, sig. = 0.001, η2=0.26), but not eye movement period (F (2,40) = 1.679, sig. = 0.201, η2=0.04). Moreover, according to post hoc, group three (EM + war) shows higher SCR than group one (EM + war + humour) (sig. = 0.022) in war period. In humour period, Group two (war + humour) has higher SCR than group one (EM + war + humour) and group four (EM + humour) (EM + war+ humour: p = 0.007, EM + humour: p = 0.003). For the recall period, there is no significant difference among groups (F (2,40) = 0.007, sig. = 0.978, η2=0.001). Furthermore, we explored the correlation between SCR and IES-R in war and humour period, which has significant difference in ANOVA. We measured these correlations by linear regression in permutation tests, which is recommended by Bishara and Hittner (2012) when the sample size is less than 20. For regression, participants with higher SCR in war video period lead to higher hyperarousal scores (coefficient = 5.006, sig. = 0.029), and participants with higher SCR in humour video period predicts higher scores in total IES-R score that is different from day 0. In another word, higher SCR in humour video period correlates with more changes in IES-R score (coefficient = -14.42, sig. = 0.022).

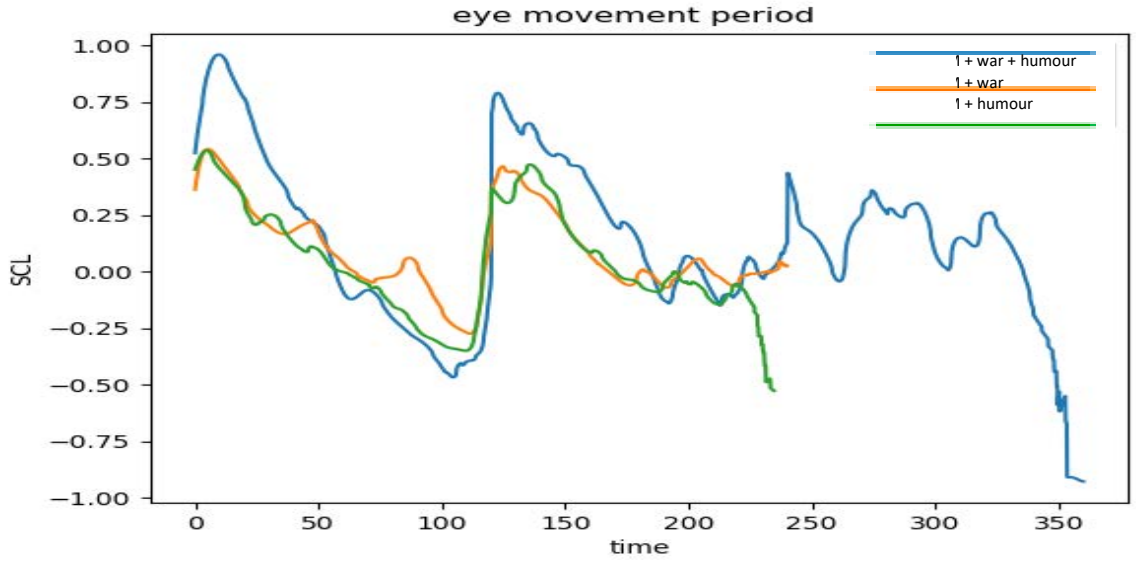

Figure 8. *Skin response level of EM + war+ humour, EM + war and EM + humour in eye movement period.*

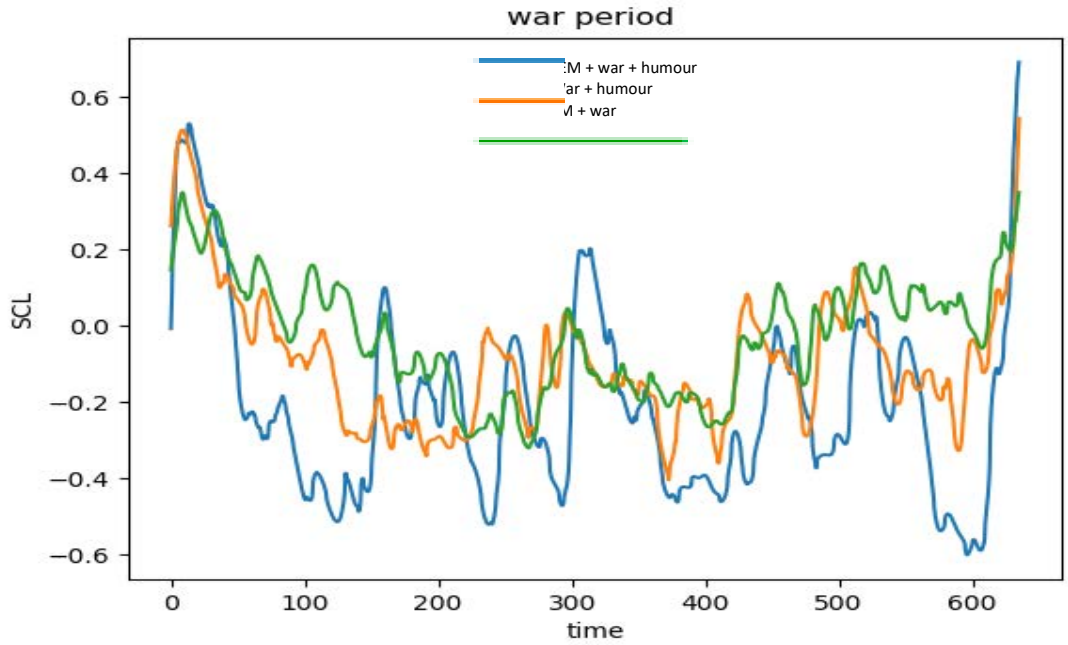

Figure 9. *Skin response level of EM + war + humour, war + humour, EM + war in war period.*

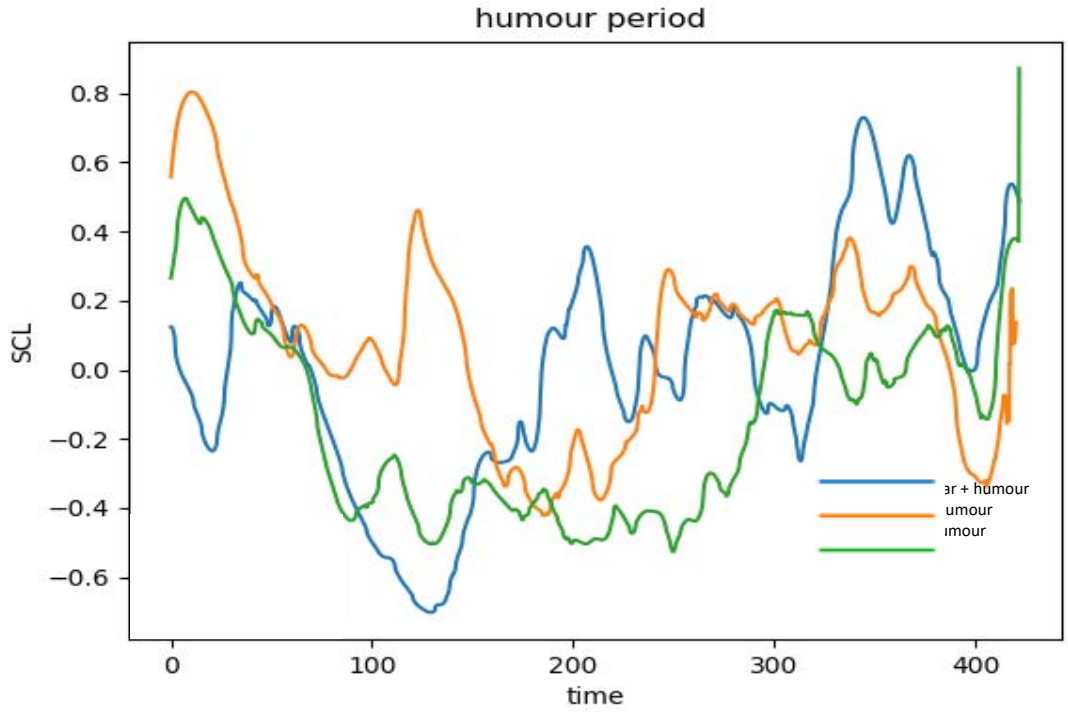

Figure 10. *Skin response level of EM + war + humour, war + humour, and EM + humour in humour period.*

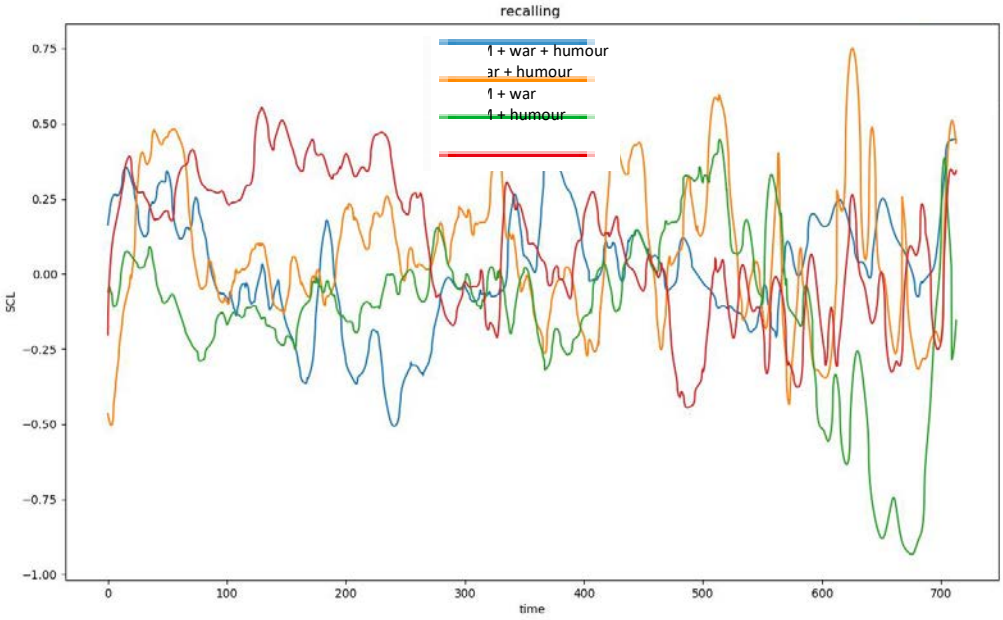

Figure 11. *Skin response level of group EM + war + humour, war + humour, EM + war, and EM + humour in recalling period.*

Discussion

In this experiment, participants in group two (war + humour) remembered most about war video clips after intervention in declarative memory tasks compared to all other groups with eye movement. Therefore, eye movement might impair the old declarative memory. Moreover, counterconditioning might help participants to integrate new memories to old involuntary memories from the results of IES-R. In IES-R, there was no difference among groups in a short term (day 0). However, there were significant differences in avoidance from day 1 and day 7, where group three (EM + war) was significantly higher than group one (EM + war+ humour). For the difference in IES-R, there is a between-group effect in total, intrusive and avoidance subscale. This is mostly contributed by the difference between group one (EM + war+ humour) and group three (EM + war) in these three subscales. Moreover, group four (EM + humour) decreased significantly less than group one (EM + war+ humour) in total score. For SCR, the one in war periods predicts hyperarousal scores, and the one in humour predicts the decreasing

in total IES-R. In addition, participants in group two (war + humour) had the highest SCR in humour video period. The below table indicates whether there is a significant difference among groups.

Table 5

The significant difference among different groups in IES-R, IES-R that different from day 0, Declarative memory task, SCR

		IES-R	IES-R that different from day 0			Declarative memory task	SCR	
Group 1	Group 2	Avoidance	Total	Avoidance	Intrusive		War	Humour
EM + war + humour	War + humour					Less details		lower
	EM + war	Lower	Decrease more	Decrease more	Decrease more		Lower	
	EM + humour		Decrease more					
War + humour	EM + war					More details		
	EM + humour					More details		Higher
EM + war	EM + humour							

Groups with without counterconditioning and eye movement (group three: EM + war; group four: EM + humour) decreased significantly less than group with complete counterconditioning and eye movement (EM + war + humour) in IES-R total scores, which means counterconditioning can help individuals reduce the impact of the trauma-like memory in daily life. From the classical fear memory paradigm, research found counterconditioning (watching positive 6-s film clips with conditional stimulus) can reduce negative stimuli valence (van Dis et al, 2019). This effect still exists in appetitive and aversive memories when research introduced counterconditioning to reduce positive stimuli valence in animal studies, and this links to increased activity in regions associated with prediction error signaling (such as thalamus, insular cortex, lateral amygdala, and the nucleus accumbens (Keller, Hennings & Dunsmoor, 2020). Therefore, counterconditioning might help participants to reduce negative emotion and evaluation after counterconditioning would integrate a history of trauma-like memory. This can also be explained by the AIP model (Shapiro, Laliotis, 2011) when counterconditioning helps participants to integrate new memory (humour video) into old memory in an active status (war video) (Shapiro, Laliotis, 2011). Importantly, group three (EM + war) decreased the least among all groups and had a significant difference from group one (EM + war + humour) in avoidance, intrusive, and total IES-R score. However, this does not correspond to declarative memory tasks.

The experiment results suggested that eye movement facilitates memory destabilization, and therefore impair the memory. When we compare eye movement + war + humour, eye movement + war, eye movement + humour, the first group undergoes a full memory

reconsolidation process from reactivation (war videos) to altering new information (humour videos); the second group only involves in reactivation by re-watching war videos; the last group involves in updating new information (humour videos) which had lower level of reactivation compare to previous two groups (retrieval from background sound in eye movement period)(Scully, Napper & Hupbach, 2017). If eye movements facilitate memory destabilization, the memory would become more vulnerable to reconsolidate updating or impairment. Then, EM + humour group would first destabilize their memories by reactivation and eye movement, and then integrate with humour video to impair the memory reconsolidation. Besides, eye movement facilitates memory destabilization in the EM + war group only and leaves the memories labile and vulnerable to be updated, but it impaired least as no counterconditioning is involved. This is consistent with Goltseker and Barak's experiment in 2017, where absence of counterconditioning within "reconsolidation window" cannot impair Cocaine seeking. Then, EM + war + humour would combine the above two processes, where it got the full process of memory reactivation and counterconditioning, and possibly have a hypercorrection effect which results in more updating (Scully, Napper & Hupbach, 2017). As a result, the memories of the EM + war + humour group were impaired most, and the EM + war group were impaired least. If eye movement impairs memory reconsolidation directly without destabilizing memory, eye movement + war group should acquire their war memories that are damaged by eye movement. In addition, EM + humour should not receive impaired memory as their memories would not destabilize without eye movement to reconsolidate (Elsey et al, 2018). As a result, the EM + war group should impair trauma-like memory more than the EM + humour group, which contradicts the results in this experiment.

In addition, it is not clear whether eye movement can enhance counterconditioning effects or not. On the one hand, EM + war + humour declined more than war + humour, but this was not statistically significant. It is possible that eye movement cannot boost the counterconditioning effect in trauma-like memory. On the other hand, there is no difference between complete counterconditioning (war + humour) and eye movement without counterconditioning (EM + war, EM + humour). If we only consider counterconditioning, it has a great impact on reducing negative valence. From Högberg, Hällström, and Sahlgrenska's study in 2018 about reducing suicide symptoms in teenagers, they found that participants decreased their negative valence significantly after counterconditioning. Then, there would be a significant difference between complete training and incomplete training. Furthermore, we should not ignore the fact that

complete counterconditioning (EM + war + humour) decreased more PTSD-like symptoms than without counterconditioning training (EM + war; EM + humour) with eye movement. As a result, counterconditioning might partly contribute to the difference between EM + war+ humour and EM + war and EM + humour in PTSD-like symptoms. If eye movement is not involved in counterconditioning training, this trend disappears when we compare counterconditioning without eye movement (war + humour) and without counterconditioning with eye movement (EM + war; EM + humour). There, eye movement might play a subtle role in both negative and positive memory. In other words, eye movement might have an impact on all kinds of memories at a medium level. Specifically, eye movement can blur the memories through memory reconsolidation, which make participants feel less vivid or emotionality about war or humour memories, while counterconditioning can help participants to reduce the negative valence in a larger effect.

Therefore, when we combine eye movement and counterconditioning together, it plays the greatest effect reducing PTSD-like symptoms. The result indicates that group one (EM + war + humour) decreases significantly more than group three (EM + war) in avoidance, intrusive, and total score.

Hence, we can also explain results in the following ways. In the beginning, counterconditioning might help participants to integrate new information with the blurred old memories, which is important as it reduces avoidance and intrusive symptoms. In avoidance scores, researchers found that greater avoidance symptomatology is associated with greater activation in emotional processing circuits when response to conditioned cues and contextual information (Sripada, Garfinkel & Liberzon, 2013). The failure to adapt to or integrate new contextual information into previously learned contingencies can also cause greater avoidance symptoms (Garfinkel and Liberzon, 2009). Moreover, PTSD intrusions are the result of a lack of memory integration and contextualization. Intrusions occur when traumatic memories are not integrated properly into autobiographical memory, as participants feel “nowness” when recalling the memory (Michael et al, 2005; van Marle, 2015).

Thus, for the EM + war + humour group, their trauma-like memory (voluntary declarative part) was reduced by eye movement, and involuntary part possibly was reduced by counterconditioning and integrated by new information (humour videos), thereby reducing negative valence about the blurred memory. However, for the EM + war group, it received

memory destabilization only and did not impair the memory reconsolidation process like EM + humour group, thereby receiving least reduction in PTSD-like memory. For hyperarousal, it can directly influence all other factors (Schell, Marshall & Jaycox, 2004), and it is more correlated to physical health and condition (Pérez, Abrams, López-Martínez & Asmundson, 2012). Therefore, hyperarousal is more disassociated from avoidance and intrusive, and has a closer link to SCR. In conclusion, we suggest that eye movement and counterconditioning might not have close connection with each other but can bring the greatest effect when we combine them together.

Nevertheless, this is based on the assumption that there is a difference between complete counterconditioning (war + humour) and incomplete counterconditioning (war or humour). Previous research about counterconditioning in episodic memory reconsolidation is mostly about maladaptive reward memory, where it focuses on appetitive counterconditioning instead of the reward one (Paulus et al, 2019). Even if there is reward counterconditioning about memory reconsolidation in rats, more evidence is still needed to support the reward counterconditioning effect about memory reconsolidation in humans (Haubrich et al, 2015). Moreover, eye movement + war and eye movement + humour might also not be equivalent to each other, as there is significant difference between eye movement + war + humour and eye movement + war in intrusive and avoidance score but not between eye movement + war + humour and eye movement + humour. First, re-watching war videos or watching humour videos might bring different valence in experiments. For instance, war video will reactivate the war memory which results in negative valence, while humour video without retrieval of the memory may provide reward stimuli. Second, eye movement might have a different impact on reactivating memory and integrating new memory. From our SCR result in humour videos, we can notice that participants with eye movement have higher SCR than participants without eye movement. However, SCR in war videos did not show the same trend as humour videos. Then, it will be worth investigating watching war videos or humour videos only without eye movement in memory training session (day 2). After that, it will be clear to investigate whether eye movement and counterconditioning interfere or not.

From declarative memory tasks, participants without eye movement (group two: war + humour) remembered the most about war video after intervention. In addition, this is mainly contributed by the difference between group two (war + humour) and group four (EM + humour), as participants in the latter group did not reactivate their memory about war videos in the second

day training. Both group one (EM + war + humour) and group three (EM + war) recall less details than group two (war + humour), and this was not a statistically significant effect. Therefore, eye movement helps to impair war video memory, but in a limited way. However, this result is different from IES-R, where eye movement did not have a substantial effect on it. Therefore, what IES-R measures (PTSD-like symptoms) are not the direct result of declarative recall. Hence, this question could turn to some interesting explorations.

First, there is a difference between declarative memory and nondeclarative memory. Declarative memory involves the conscious and effortful recall of facts while recalling non-declarative memory is more about activation from initial skills or tasks without any awareness of memory content (Kern et al, 2010). Importantly, the key differences between declarative memory and no-declarative memory are consciousness and awareness. Furthermore, declarative memory heavily relies on medial temporal lobe (MTL), but non-declarative memory depends on different brain regions with multiple coherent systems (Reber, 2008). A good example in declarative memory can be recalling word lists, and for non-declarative memory, it can be fear response or feeling from classical conditioning or counterconditioning like in the human fear memory paradigm (Fernández et al, 2016). Moreover, Brewin did meta-analysis on traumatic film paradigm in 2014 and classified the tasks in two types: voluntary episodic recall and involuntary memory task. For voluntary episodic memory, it included cued recall, recall sequences, and recognition. For involuntary memory tasks, it included an intrusive diary, IES-R (intrusion). According to dual representation theory, intrusion is produced by long-term perception representations that were captured by trauma, with minimal conscious attention and can be accessed involuntarily. Another memory called voluntary memory, which are trauma representations that need more conscious, and being voluntarily accessible, verbalizable. It is also able to interact with other information in autobiographical memories (Brewin, Dalgleish & Joseph, 1996).

In this experiment, it is clear that the declarative memory task measures voluntary declarative memory, and IES-R measures involuntary memory (Lau-Zhu, Henson & Holmes, 2019). However, there is a debate about whether IES-R measured declarative memory or not. As we mentioned before, the IES-R scores test is a good measurement for PTSD-like symptoms and has been widely used in testing experimental analogue of traumatic events (James et al, 2016). Moreover, it measures participants' symptoms from intrusive, avoidance, and hyperarousal perspectives, which refer to participants' feelings about the analogue trauma and how it affects

their daily life. For intrusive, it often takes the form of sensory-perceptual impressions (e.g. pictures in the mind's eye) that intrude involuntarily into consciousness (James et al, 2016). However, when we look the questions in intrusive scale at IES-R, we also can find the half of the questions (Q1,Q2,Q14,Q16) are related to individuals' perception or emotion value about the trauma-like memory, which is consistent with the definition about non-declarative memory. Furthermore, the avoidance scale can be considered non-declarative memory. Individuals can acquire evaluation information such as negative value from non-declarative memory. Associative learning of fear is a good example for this kind of memory (Squire & Dede, 2015). Normally, animals freeze when they face dangerous situations. However, they learnt avoidance behaviours to escape the situations (Moscarello & LeDoux, 2013). In this experiment, avoidance scale can measure participants' avoidance behaviours towards traumatic videos, which are not present though recall but perception. As a result, IES-R measures both involuntary declarative and nondeclarative memory, and we need to distinguish it from the intrusive diary which only tests involuntary declarative memory. Thus, IES-R might not be as sensitive as the intrusive diary in involuntary declarative memory, as not every scale measured a significant group difference in this experiment. However, we cannot deny that it is a good tool to measure the PTSD-like symptom, as it has high internal consistency both for pre-existing symptom levels ($\alpha = .87$) and at 1-week follow-up ($\alpha = .89$) (White & Wild, 2016). It also shows good validation in PTSD-like symptoms in the traumatic film paradigm (Streb et al, 2015; 2016). It also helps us to understand more about how eye movement and counterconditioning reduces participants' PTSD-like symptoms in not only intrusive, but also avoidance and hyperarousal.

Then, eye movement can have different impacts on these two types of memories. Additionally, the degree of involuntary memory and voluntary explicit memory should be unrelated, and they are functionally independent from each other (Brewin, Dalgleish & Joseph, 1996). In our experiment, participants with eye movement recall less details than participants without eye movement. Thus, eye movement can impair the voluntary declarative memory. In the beginning, eye movement can reduce the vividness and emotionality in memories. This is supported by previous research from Houben and her colleagues in 2020. They generated 15 studies about dual tasks about emotionality and vividness in negative autobiographical memory. As result, both eye movement and alternative dual tasks (e.g. verbal tasks) can reduce the vividness and emotionality of autobiographical memory in acute stage, with a medium effect size (Cohen's $d=0.59$) for vividness and a small effect size (Cohen's $d = 0.28$) for emotionality.

Furthermore, the retrieval of autobiographical memories with less emotionality is associated with less activation in the hippocampus (Addis et al,2004). Quantitatively, participants without eye movement had the best declarative memory, although the current design did not permit a direct analysis of the effect of eye movement. Furthermore, results from experiments demonstrate this effect might last in the long term as participants in a war + humour group recall more details about war videos than groups with eye movement after a week.

However, for involuntary memory, there is no solid evidence to support that eye movement can reduce it. According to the dual representation theory, involuntary memory can be weakened by a secondary task while the trauma images are encoded. However, this is only accomplished by a perception task which would compete for the resources. This is confirmed by thirteen studies, where they demonstrated that a visuospatial task reduced the involuntary recall of images from the film over the following weeks, compared to non-task groups (Brewin, 2014). However, when we looked back at the results in this experiment, there is no difference between participants with eye movement (EM + war + humour; EM + war; EM +humour) and without eye movement (war + humour) from IES-R. It is possible that eye movement taxes less working memory resources than the Tetris task (Engelhard, van Uijen, & van den Hout, 2010). From inverted U theory, not taxing working memory or heavily taxing it during the recall does not change the memory, but taxing at a level somewhere in between does produce effects (Engelhard, van den Hout & Smeets, 2011). Furthermore, eye movement requires less working memory resources than complex visuospatial tasks such as computer games. Then, eye movement is not enough to tax working memory, and therefore cannot reduce the intrusion and emotionality in involuntary memory. As a result, participants with eye movement did not decrease their PTSD-like symptoms more than participants without eye movement.

In addition, it is quite interesting that eye movement can reduce free recall (voluntary memory) but not intrusion (involuntary memory), which contradicts previous experiments (Lau-Zhu, Henson & Holmes, 2019). This could be explained by the inverted U theory and dual representation theory too. First, eye movement might be at an appropriate level for taxing working memory in voluntary declarative memory, but Tetris games might be too heavy for it. Second, Tetris games might be at an appropriate level for involuntary declarative memory, but eye movement might not be effective enough. Furthermore, Tetris games are also not effective for involuntary nondeclarative memory (implicit priming), and eye movement plays the same role here (Lau-Zhu, Henson & Holmes, 2019). Then, we assume that involuntary memory

needs less working memory resource than voluntary memory, non-declarative memory needs less working memory resource than declarative memory. Therefore, eye movement can affect voluntary memory but not involuntary declarative/nondeclarative memory. However, further experiments about implicit priming about traumatic movies need to be done in the future.

Moreover, for SCR in humour period, participants without eye movement (group two: war + humour) have significantly higher SCR than participants with eye movement (group one: EM + war + humour; group four: EM + humour), which means participants without eye movement (war + humour) have more positive response or emotionality than group with eye movement during the humour video. This is consistent with previous findings about eye movement, where it reduces the emotionality in positive memory (Engelhard, van Uijen, & van den Hout, 2010). Therefore, participants without eye movement receive higher arousal in humour videos, and thereby might slightly promote the counterconditioning effect, which helps them to reduce PTSD-like symptoms. This is confirmed by SCR in the humour period, when SCR predicts the decreasing of total IES-R score. However, it is important to notice that the changes of SCR cannot explain most of the changes in IES-R score. From regression, we can notice that the coefficient of SCR in the humour period is -14.42, and the difference of SCR units between war + humour and other groups (EM + humour; EM + war + humour) is less than 0.04 units. Additionally, the difference between war + humour and other groups in IES-R score that are different from day 0 are 5.1 and 7.5. Therefore, it only can explain 0.576 IES-R score out of 5.1 or 7.5. Hence, we need to notice that this effect might not play an important role in IES-R score, as SCR presents involuntary nondeclarative memory (emotionality or physical reactions) while IES-R score measures both involuntary declarative and nondeclarative memory.

However, this is inconsistent with war video clips as there is no similar pattern, where EM + war has a significantly higher SCR than EM + war + humour, and also there is no difference between EM + war and war + humour. We need to notice that both EM + war and EM + war + humour have the same intervention in war video. Then, we would suspect that participants in EM + war have higher SCR due to their individual difference. In addition, there is no difference between war + humour and EM + war, which indicates that eye movement did not help participants receive less arousal in war video period. This may be explained by the mechanism of SCR. For SCR, the signal is generated by the physiological response of sweat glands on skin, and this is well connected with hypothalamus (the central brain area controlling vegetative functions or processes that are related to the maintenance of life) (Boucsein, 2012).

The hypothalamus is further controlled by the limbic system, especially the amygdala (an area involved in emotions) and hippocampus (an adjacent area associated with the formation of memories). In addition, amygdala-induced SCR have higher amplitude than hippocampus-induced SCR (Christopoulos, Uy & Yap, 2019). It is possible that participants' immediate reaction to war video is more related to amygdala-induced SCR instead hippocampus-induced SCR, while SCR in humour video period has more relation to hippocampus-induced SCR about involuntary nondeclarative memory. This is consistent with SCR in war video, when it predicts the hyperarousal score and participants with higher SCR have higher hyperarousal score in IES-R.

In conclusion, eye movement does help participants to impair old voluntary declarative memory through facilitating memory destabilization, and counterconditioning helps participants to integrate new memory/emotion into involuntary memory. However, further studies are needed to investigate the interference between eye movement and counterconditioning in memory reconsolidation.

Experiment 2

Introduction

Participants from different cultures might perceive and process differently through memory reconsolidation. First, cultural differences can also lead to different levels of vulnerability according to self-related memory. Despite the fact that there are individual and situational differences in specific societies, western countries are more likely to have individualistic cultures while eastern countries have collectivistic cultures. Individuals from individualistic cultures tend to distinct themselves from others and contribute to this autonomous self-construal. However, collectivistic cultures have less self-concept but tend to fit to other and surrounding environments (Markus & Kitayama, 1991). For trauma-like memory, individuals would have autonomous orientation in this memory. However, this may violate collectivistic cultures, which result in enhanced trauma-like memory (Jobson, 2009). Thus, participants in China might experience a higher trauma-like experience in the beginning compared to participants in the UK in the beginning. When referring to the trauma film paradigm, there are experiments related to cognitive distraction and attentional bias in only Chinese participants yet (Dou et al, 2014; Kang et al, 2012). However, we still can gain information about whether Chinese participants can form trauma-like memories from traumatic films and whether self-construals can increase their intrusive memory through these experiments. From Dou and his colleagues' study, they found participants significantly increased subjective ratings of negative

emotions (such as anger, disgust, sadness) after watching traumatic videos (sig.<0.001). Moreover, their Blood Volume pulse, breath, heart rate increased significantly after watching traumatic video (sig. <0.001). Another study shows slightly different results from this one when Physiological parameters decreased but not significant. Therefore, we can at least confirm that Chinese participants will form trauma-like memories from the traumatic movie paradigm, and possibly be more sensitive than participants in the UK.

EMDR has a relatively short history in China. This therapy was not introduced to Chinese psychology therapists until 2002 (Lv, Qian, 2010). After that, psychologists in China started to practice this therapy, and validate the efficacy in Chinese people. In 2008, a considerable number of psychologists applied EMDR to survivors from the earthquake in Sichuan, 12th May. Psychologists found this therapy is very effective in stabilizing survivors' mental status and preventing further mental issues (Lv, Qian, 2010). Moreover, Chen and her colleagues in 2015 compared the recovery status between EMDR and CBT (cognitive behavioural therapy) in individuals who suffer from trauma. They found that both EMDR and CBT can reduce trauma symptoms (i.e. intrusive memory, flash back). Furthermore, individuals reduced their anxiety and depression significantly after receiving EMDR (Chen et al, 2015). This is confirmed by Wang and her colleagues when they replicated Chen's study in 2017. Moreover, they found EMDR can reduce individuals' trauma symptoms in the longer term compared to CBT. For healthy individuals, research found that Chinese participants decreased the vividness and emotionality of their autobiographical memory after eye movement (Qin, 2013). Therefore, we proposed that EMDR is an effective treatment for Chinese and eye movement plays a role in it.

There might be differences in cognitive strategies when talking about cultural differences. From Masuda and Nisbett (2006) research about attention and perception study between eastern and western culture, they found that western students tend to focus on changes in specific objects while eastern students focus on changes in context. Similarly, a meta-analysis found that individualistic cultures prefer use of contrast and separation while collectivistic cultures prefer assimilation and connection in perception strategies. Moreover, participants performed faster and more accurately when the task is culturally congruent with their perception strategies (Oyserman, Sorensen, Reber, & Chen, 2009). Therefore, participants with eastern culture would be more sensitive about prediction error or retrieval-extinction training, which is consistent with findings from some Chinese researchers when they replicated the

human fear memory paradigm from Kindt and her colleagues in 2013 in extinction training and prediction error. All of them disrupted fear memory successfully through propranolol, prediction error, or extinction training while some experiments with western participants received negative results (Sevenster, Beckers & Kindt, 2012; Li et al, 2017; Yang et al, 2019; Deng et al, 2020). In these experiments, participants with moderate conditioned stimuli as retrieval cue received fear memory mostly compared to other levels of conditioned stimuli (Li et al, 2017). In addition, participants with single prediction error have less fear compared to participants with multiple prediction error when conditioned stimuli presented (Chen et al, 2018). Therefore, Chinese participants might associate war video and humour video better than British participants. As a result, Chinese participants might update their trauma-like memory better and decrease more in IES-R score.

Due to Covid-19, it is necessary to transfer the experiment into an online platform. However, participants might be distracted by the environment and would not devote most of their attention to tasks (Gould, Cox, & Brumby, 2013). As a result, they might not remember the video well and are less likely to decrease more compared to participants in the lab. Thus, for online experiments, the experimenter will first ask participants to attend the experiment online via computer in a quiet room. Then, they will ask to mute their phone and watch all the experiment procedures on their laptop. In the end, participants are required to complete the different sections in the same room with the same laptop.

Moreover, participants might misunderstand the instruction or even skip the instruction. In addition, the rate of understanding for complex tasks (e.g. multi-categories task) is less than simple tasks (e.g. scoop task) (Finley & Penningroth, 2015). Therefore, participants will be asked an attentional question to confirm their attendance. Then, the experimenter simplified all memory training in a video to avoid mis-operation. For Chinese participants, the experimenter translated all the questionnaires and experiment instruction in Chinese to make sure Chinese participants would not misunderstand the task. In addition, the traumatic and humour videos did not involve any conversation with languages, and they are mixed with western and eastern movies, individuals that come from different countries can still receive the same emotion from these videos.

From Gould and her colleagues' experiment in 2013 about comparing online and lab data from time sensitivity experiments, they suggested that experiments should support and give

participants instructions when they need. Therefore, the experimenter will give voice instruction online to avoid all the possible misunderstanding during the experiment. The experimenter also will give a voice call for the declarative memory task on the last day to help participants recall the same as participants who did in the lab.

Method

Participants

We recruited 35 healthy participants from Southwest University in China and 24 healthy participants were recruited from the University of Birmingham, 26 participants completed their experiments in person, and 33 participants completed their experiments online. Six of participants were screened out in session 1 due to high scores in anxiety sensitivity index, five of them did follow the instruction properly (age from eighteen to twenty-six; fourteen males and thirty-two females). Participants who have anxiety disorder or post-traumatic stress disorder were excluded. Moreover, participants who scored 36 or more in the anxiety sensitivity index (Peterson & Heilbronner, 1987) were screened out from this study due to the possible risk when watching the traumatic video. For the experimental group, there are 34 participants in person / 15 online: 33 UK participants/16 Chinese participants. For the control group, there are 10 participants in person/ 18 online: 8 UK participants/20 Chinese participants.

Design

This experiment constituted two interventions (control group: no interventions on the second day; experimental group: eye movement + war video + humour video on the second day), and we compared the difference in country (China vs United Kingdom) and experimental form (online vs in person). Due to the misconducting and difficulty recruiting online, In the end, we had an experimental group and control group in Chinese and UK within person form, UK with online form. Chinese online for control group.

Table 6

Number of participants in each group.

Type	Experimental group (number of people)	Control group (number of people)
UK-in person	18	N/A
UK-online	15	8
China-in person	16	10
China-online	N/A	10

Measurement

For the subjective measurements in this experiment, the researchers used Impact Event Scale-Revision (IES-R) (Weiss, Marmar, 1997), and the primary measurement focused on total score and intrusive subscale in IES-R.

Material and procedures

The experimental procedures are similar to experimental 1 except:

- Online groups conducted the whole experiment online. The experimenter introduced all procedures via voice call.
- Control group did not have training on day 0 (which includes eye movement, war/humour video clips).

Data transformation and statistical analysis

Impact Event Scale-revised (IES-R)

All scores were first calculated and analysed in the original format. Then, all scores from day 1 to day 7 subtracted from scores in day 0 (baseline). In this result, we were particularly focused on total score and intrusive score in IES as the primary measurements according to James' meta-analysis in 2016 about traumatic film paradigm.

Statistic tools

This experiment used the same statistical tools as experiment 1. We will first check whether experimental groups have less PTSD-like symptoms than control groups. For the control group, we do not need to use the imputation method as all participants in the control group fill in the questionnaires without missing. As a result, we will know if China in person and UK online groups reduce their PTSD-like symptoms from eye movement + counterconditioning training as UK in person group. If so, we will then apply two-way ANOVA and multiple comparisons to the experimental groups (China in person; UK in person; UK online) and control groups (China online; China in person; UK online), and check whether there is a group and day difference in IES-R scores. We will further to check the ANOVA assumption about the normality (shapiro test) and especially the variance homogeneity (modified levene's test) in these datasets, as F test is more sensitive when homogeneity assumption is violated (Blanca et al, 2017). For levene's test, we follow the advice from Parra-Frutos and Parra-Frutos in 2013, where we use Keyes and Levy adjustment from unequal and small sample size.

Result

IES-R in original score

Experimental effect in China in person and UK online group

China in person

From two-way mixed ANOVA, we found there are day differences in total F (6,102) =3.516, η^2=0.024, $sig._{total}$ =0.003) and intrusive (F(6,102) =3.256, η^2=0.034, $sig._{intrusive}$ =0.032). From Bayesian two-way mixed ANOVA, there is a day difference in total ($BF._{incl\text{-}totsl}$ = 871.806). In general, there is no group difference between control and experimental group, which means participants with eye movement + counterconditioning training did not receive lower scores than participants without training.

Table 7

Two-way mixed ANOVA for IES-R score from day 1 to 7 in total, intrusive, avoidance in China in person (control group vs experimental group).

	Multivariate test	Mauchly's test	Within-subject effect (with effect size)		Between-subject effect (with effect size)
			day	Day*group	group
Total	0.500	0.059	0.003* (0.432)	0.219 (0.010)	0.412 (0.040)
Intrusive	0.485	0.002*	0.032* (0.034)	0.378 (0.011)	0.984 (0.000)
Avoidance	0.386	0.002*	0.413 (0.005)	0.349 (0.006)	0.324 (0.057)

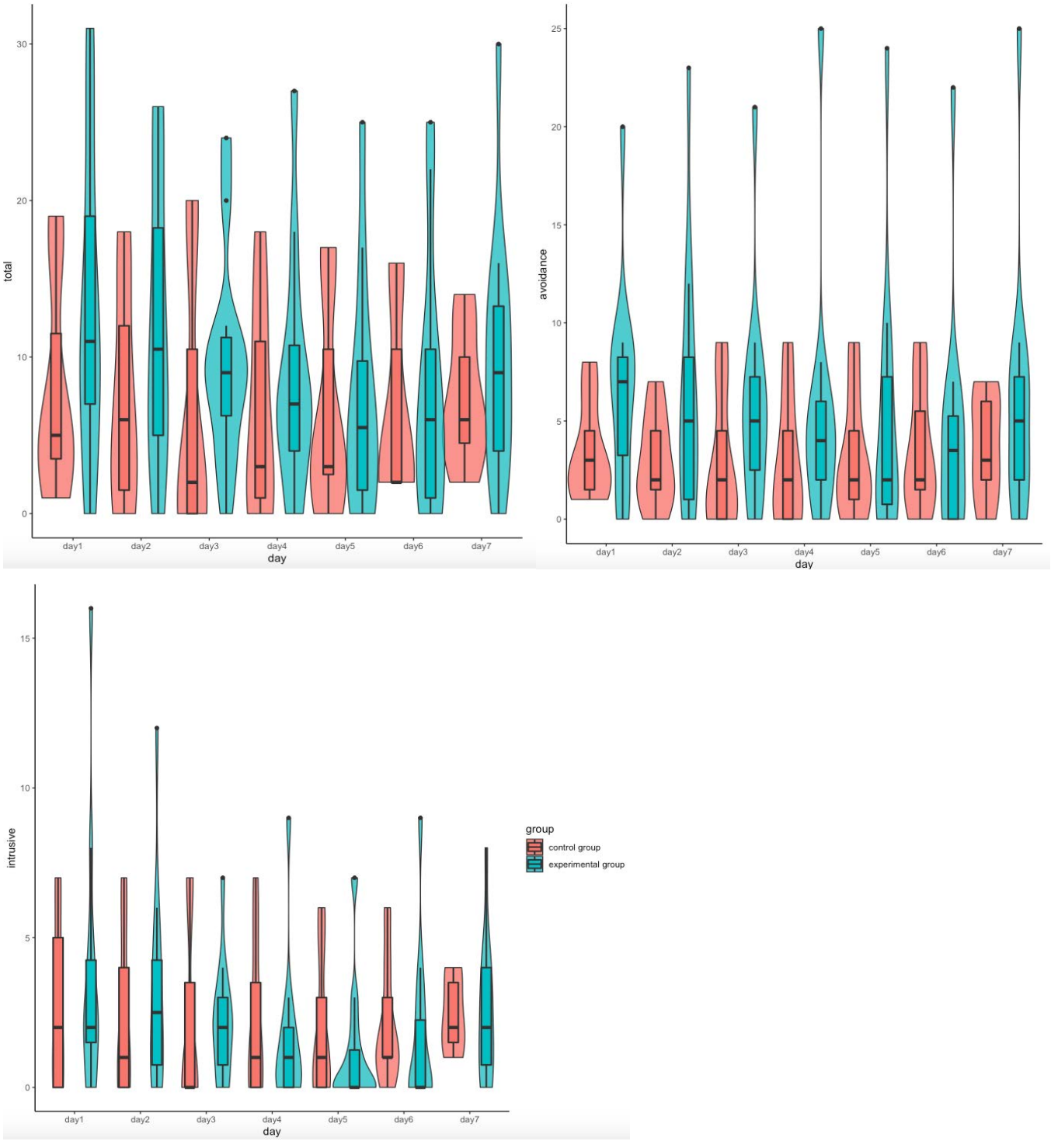

Figure 12. *Total, Intrusive, and Avoidance score of IES-R from day 1 to 7 in total, intrusive, avoidance in China in person (control group vs experimental group).*

UK online

From two-way mixed ANOVA and Bayesian two-way mixed ANOVA, we found there is no difference between experimental and control group. Then, participants with eye movement + counterconditioning did not receive lower IES-R scores than participants without training.

Table 8

Two-way mixed ANOVA for IES-R score from day 1 to 7 in total, intrusive, avoidance in UK online (control group vs experimental group).

	Multivariate test	Mauchly's test	Within-subject effect (with effect size)		Between-subject effect (with effect size)
			day	Day*group	group
Total	0.458	0.736	0.327 (0.009)	0.076 (0.019)	0.736 (0.006)
Intrusive	0.485	0.341	0.358 (0.012)	0.438 (0.011)	0.400 (0.038)
Avoidance	0.385	0.850	0.429 (0.009)	0.086 (0.023)	0.850 (0.002)

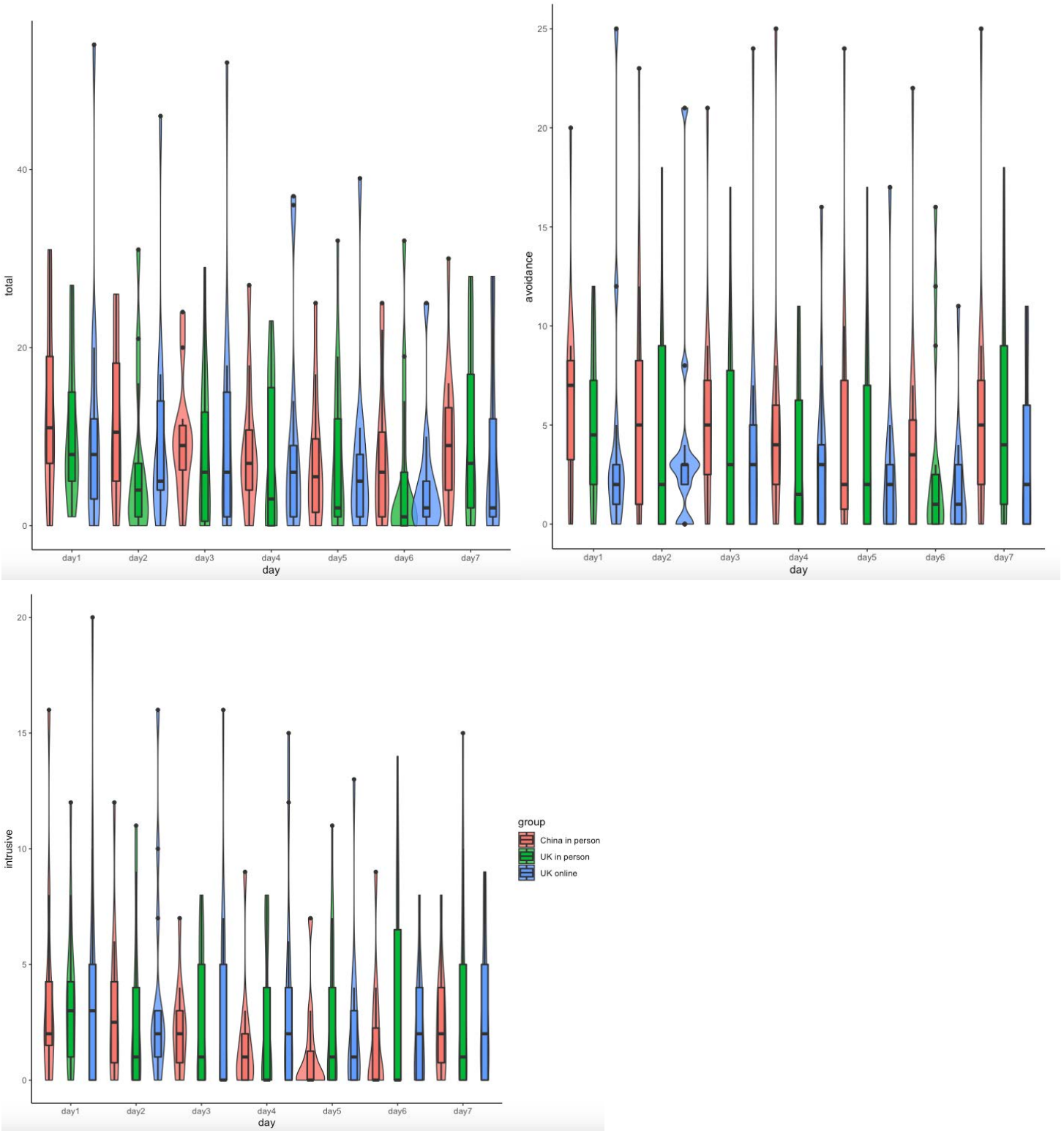

Figure 13. *Total, Intrusive, and Avoidance score of IES-R from day 1 to 7 in total, intrusive, avoidance in UK online (control group vs experimental group).*

Experimental group

For the UK in person group, there is only difference in avoidance score between eye movement + war + humour (experimental group) and EM + war (group). Therefore, we will compare the difference in IES-R scores among experimental groups (UK in person; UK online; China in person) to check whether different types or nations will have influence on the treatment (eye movement + counterconditioning). From two-way mixed ANOVA with original data, we found there are day differences in total F(6,246)=6.772, η^2=0.023, sig.total =0.001), avoidance(F (6,246) =4.833, η^2=0.029, sig. avoidance =0.001), and intrusive (F(6,246) =5.344, η^2=0.016, sig.intrusive =0.001). For the imputed dataset, there is only a day difference in intrusive (F (6,246) =5.344, η^2=0.29, sig.intrusive =0.001). From Bayesian two-way mixed ANOVA, there are day differences in total (BF. incl-totsl = 1413.315), avoidance (BF. incl-avoidance = 61.314), and intrusive (BF. incl-intrusive = 103.809). In general, there are no group or day*group effects on IES-R score. Therefore, there is a day difference in IES-R scores, but different nations or types did not influence the training effect.

Table 9

Two-way mixed ANOVA for IES-R score from day 1 to 7 in total, intrusive, avoidance among groups (UK in person, UK online, China in person).

	Multivariate test		Mauchly's test		Within-subject effect				Between-subject effect (with effect size)	
					day		Day*group		group	
	original	imputation	original	imputation	original	imputation	original	imputation	original	imputation
total	0.212	0.256	0.001*	0.110	0.001* (0.023)	0.110 (0.18)	0.289 (0.012)	0.375 (0.14)	0.136 (0.125)	0.535 (0.00)
intrusive	0.296	0.112	0.001*	0.000*	0.001* (0.029)	0.832 (0.06)	0.729 (0.012)	0.253 (0.08)	0.338 (0.078)	0.862 (0.00)
avoidance	0.311	0.004	0.001*	0.012*	0.001* (0.016)	0.023* (0.23)	0.731 (0.007)	0.469 (0.10)	0.144 (0.122)	0.557 (0.00)

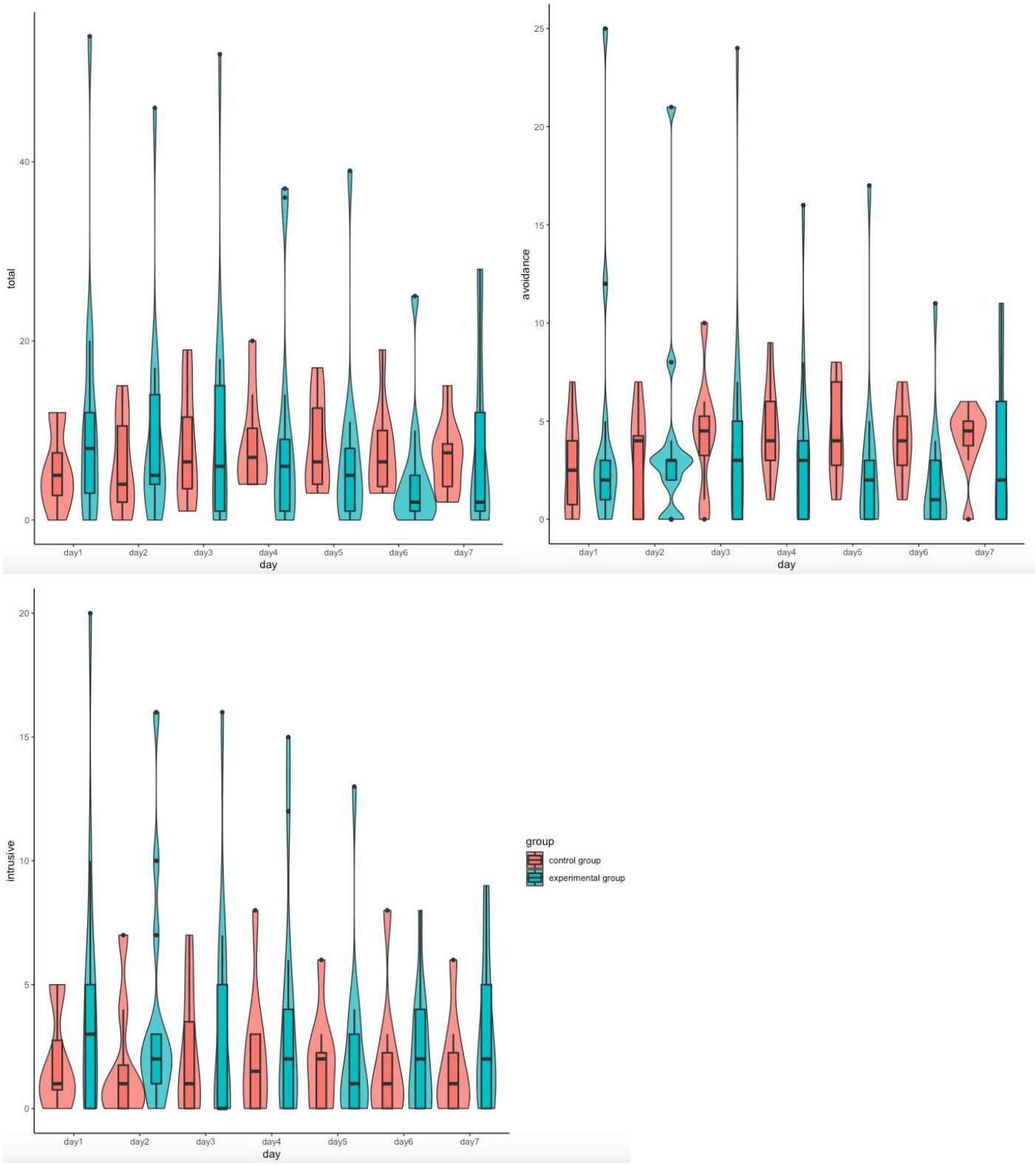

Figure 14. *Total, intrusive, and avoidance score from day 1 to 7 among groups (UK in person, UK online, China in person).*

Control group

From two-way mixed ANOVA, we found there are no group and day differences in total, avoidance, intrusive score. There are interaction effects between day and group in total $F(12,126)=3.281$, $\eta^2=0.052$, $sig._{total}=0.004$) and avoidance($F(12,126)=2.652$, $\eta^2=0.044$, $sig._{avoidance}=0.012$) score. Moreover, Bayesian two-way mixed ANOVA did not have any significant effect. As a result, there is no group or day effect on IES-R score, and there is limited evidence to support the day* group effect. Thus, participants with different types or different nations had the same IES-R score after watching war video clips in a relatively long term.

Table 10

Two-way mixed ANOVA for IES-R score from day 1 to 7 in total, intrusive, avoidance among groups (China in person, UK online, China online).

	Multivariate test	Mauchly's test	Within-subject effect (with effect size)		Between-subject effect (with effect size)
			day	Day*group	group
Total	0.120	0.002*	0.419 (0.007)	0.004* (0.044)	0.102 (0.194)
Intrusive	0.186	0.001*	0.075 (0.023)	0.186 (0.03)	0.396 (0.084)
Avoidance	0.391	0.021*	0.997 (0.000)	0.012* (0.052)	0.085 (0.209)

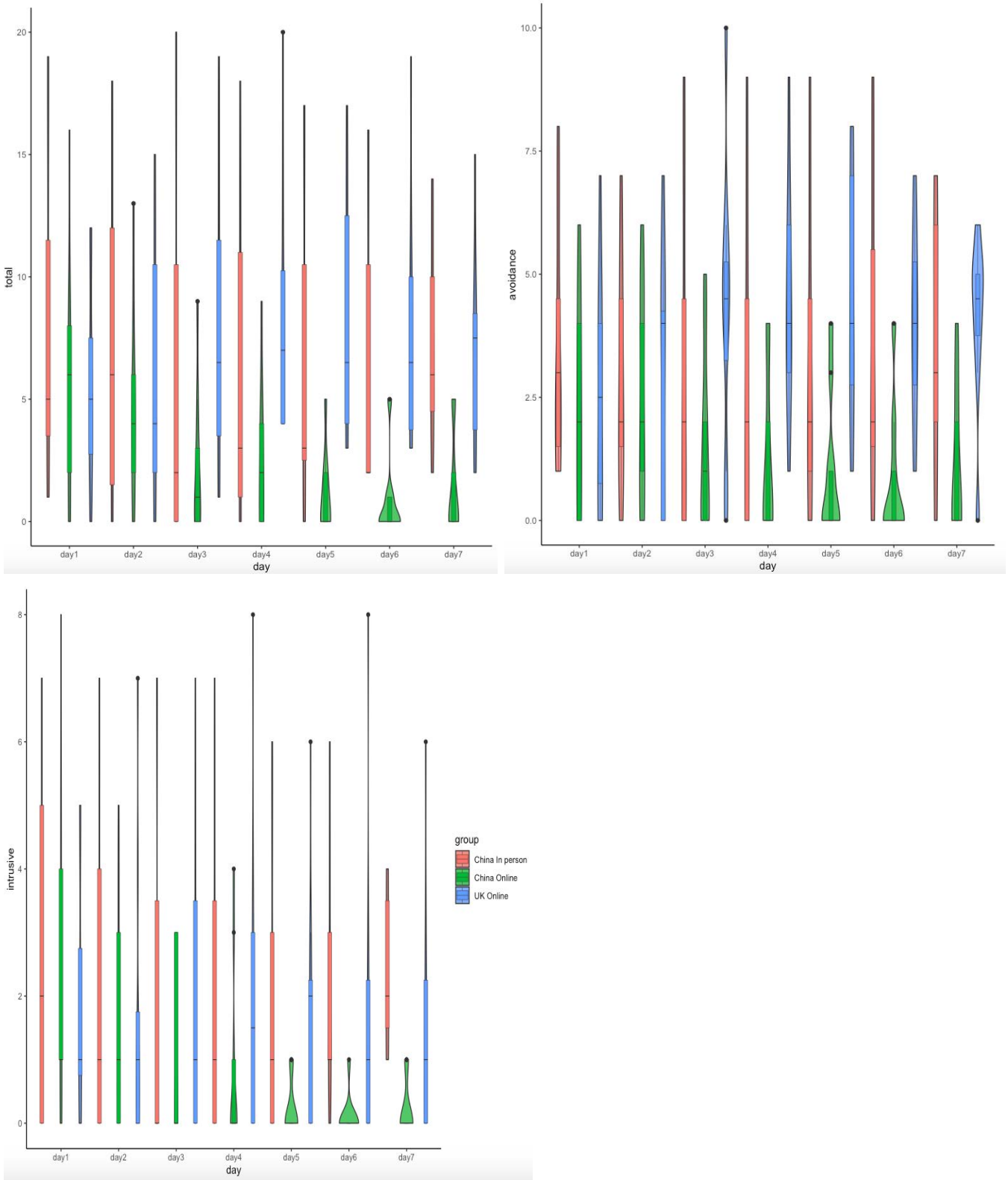

Figure 15. *Total, intrusive, and avoidance score from day 1 to 7 among groups (China in person, UK online, China online).*

Short-term effect after reactivation (scores in day 0)

Since there is no difference in IES-R score across a week, then we want to investigate whether it has the same trend in the short-term.

Experimental effect in China in person and UK online group

China in person

From one-way mixed ANOVA, we found there is a difference in total score ($F(1,20) = 6.429$, $\eta^2=0.274$, sig.total =0.026), while the experimental group had higher scores than the control group in total score. Moreover, we did not find this trend through Bayesian ANOVA. Therefore, participants with eye movement + counterconditioning training had higher IES-R score than participants without training after watching war video on day 0.

Table 11

One-way ANOVA for IES-R score on day 0 in total, intrusive, avoidance between control and experimental group (China in person).

	Levene's test	Between-subject effect (with effect size) group
total	0.365	0.026* (0.274)
avoidance	0.468	0.062 (0.190)
intrusive	0.605	0.196 (0.116)

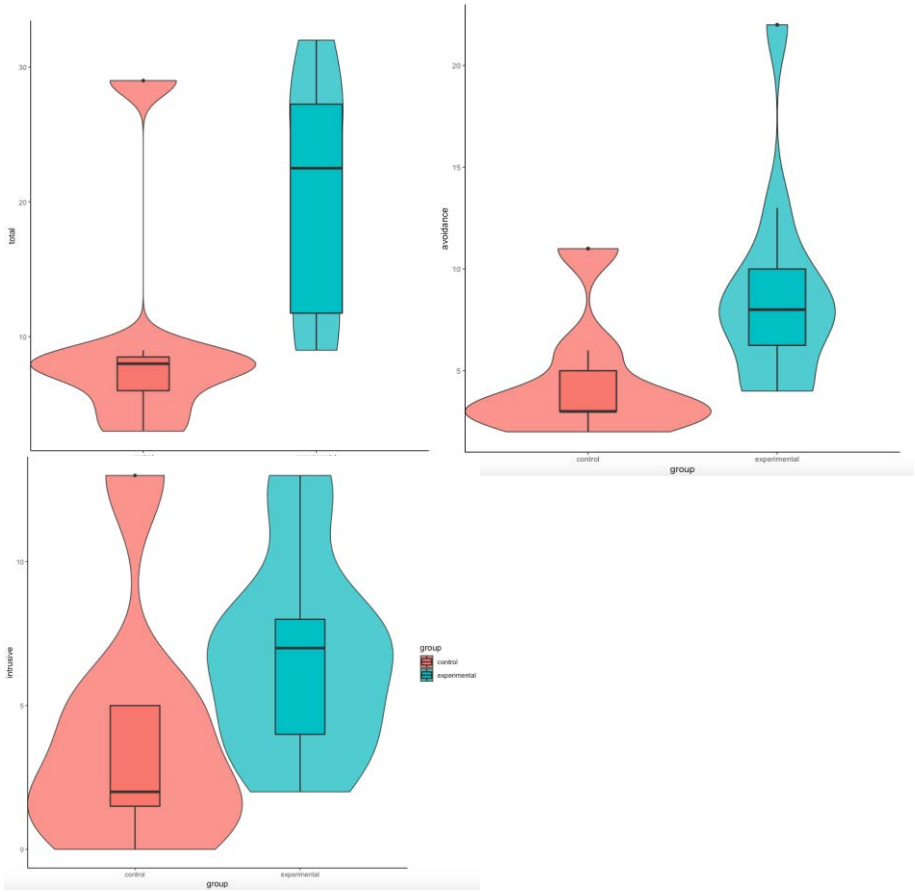

Figure 16. *Total, Intrusive and Avoidance score of IES-R on day 0 between control and experimental group (China in person).*

UK online

From one-way mixed ANOVA, we found there is no significant difference among groups. Moreover, we did not find this trend through Bayesian ANOVA. Then, there is no difference between participants with training and without training in IES-R after watching war video immediately on day 0.

Table 12

One-way ANOVA for IES-R score on day 0 in total, intrusive, avoidance between control and experimental group (UK online).

	Levene's test	Between-subject effect (with effect size)
		group
total	0.033*	0.143 (0.074)
avoidance	0.017*	0.581 (0.011)
intrusive	0.348	0.154 (0.104)

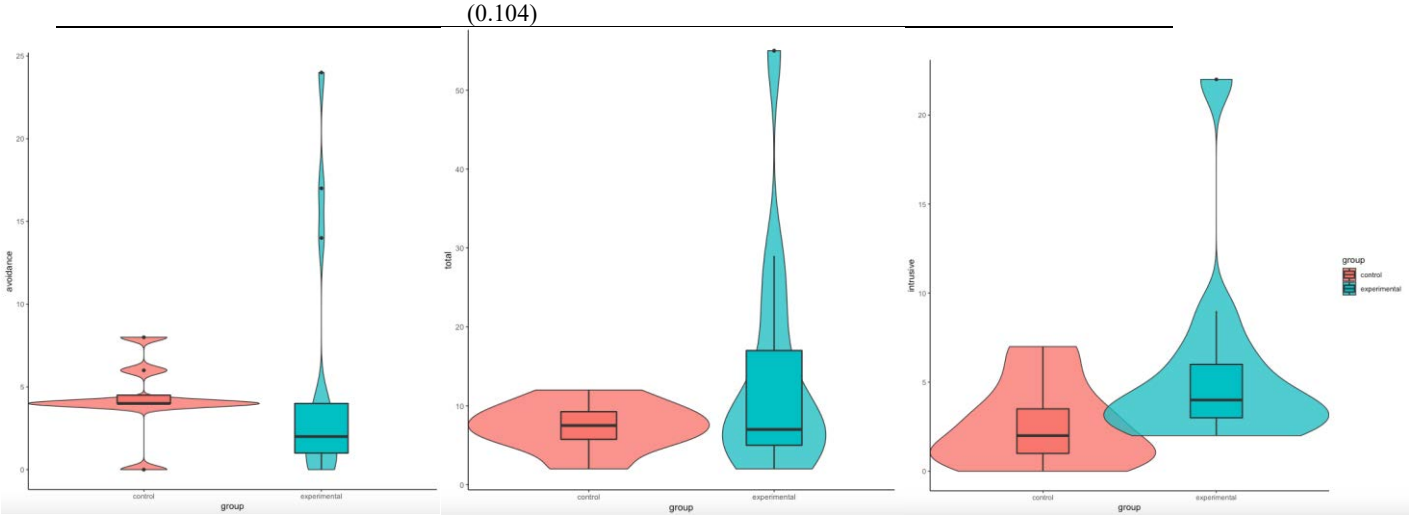

Figure 17. *Total, Intrusive and Avoidance score of IES-R on day 0 between control and experimental group (UK online).*

Experimental group

From one-way ANOVA, we found there is no significant difference among groups. Moreover, we did not find this trend through Bayesian ANOVA. Therefore, participants from different nations and types received the same IES-R after watching war video on day 0.

Table 13

One-way ANOVA for IES-R score on day 0 in total, intrusive, avoidance among groups (China in person, UK online, UK in person).

	Levene's test	Between-subject effect (with effect size)
		group
total	0.170	0.108 (0.109)
avoidance	0.162	0.175 (0.090)
intrusive	0.406	0.225 (0.080)

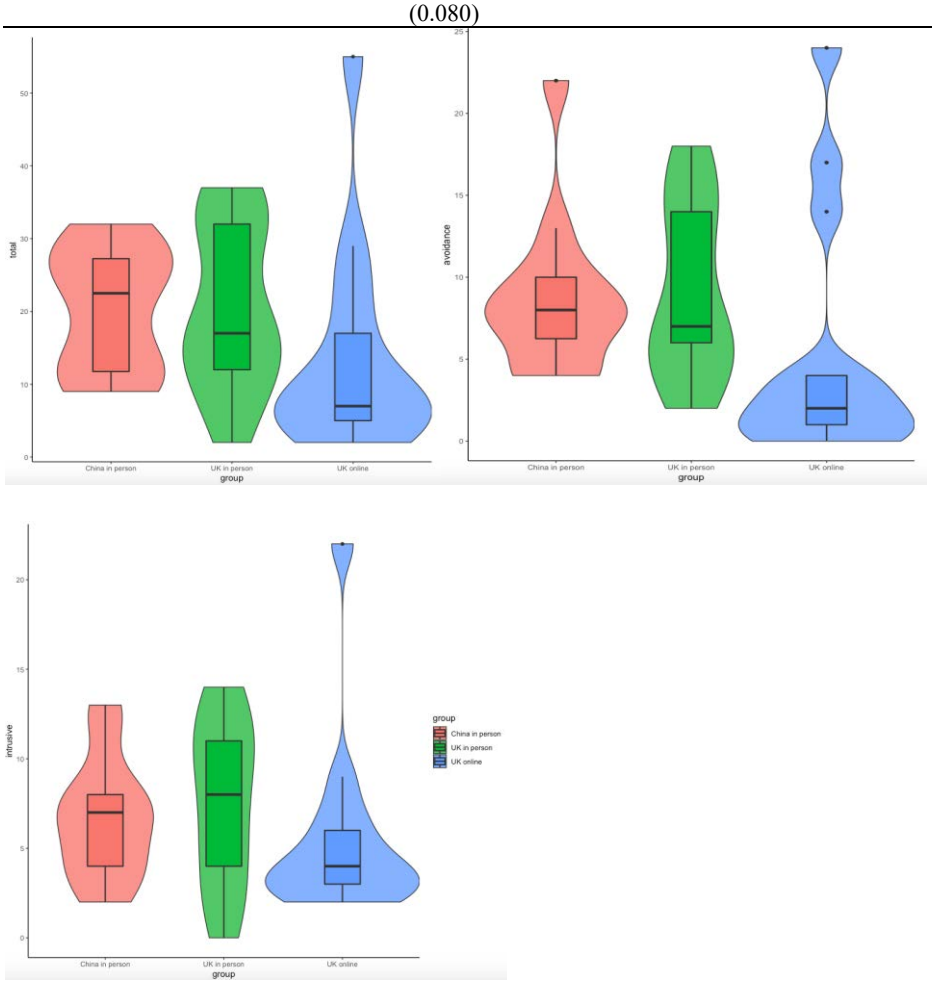

Figure 18. *Total, Intrusive and Avoidance score of IES-R on day 0 among groups (China in person, UK online, UK in person.*

Control group

From one-way ANOVA, we found there is no significant difference among groups in total, avoidance, and intrusive scores. Moreover, we did not find this trend through Bayesian ANOVA.

Table 14 *One-way mixed ANOVA for IES-R score from day 0 in total, intrusive, avoidance among groups (China in person, China online, UK online).*

	Levene's test	Between-subject effect (with effect size)
		group
total	0.030*	0.122 (0.649)
avoidance	0.003*	0.624 (0.295)
intrusive	0.268	0.155 (0.391)

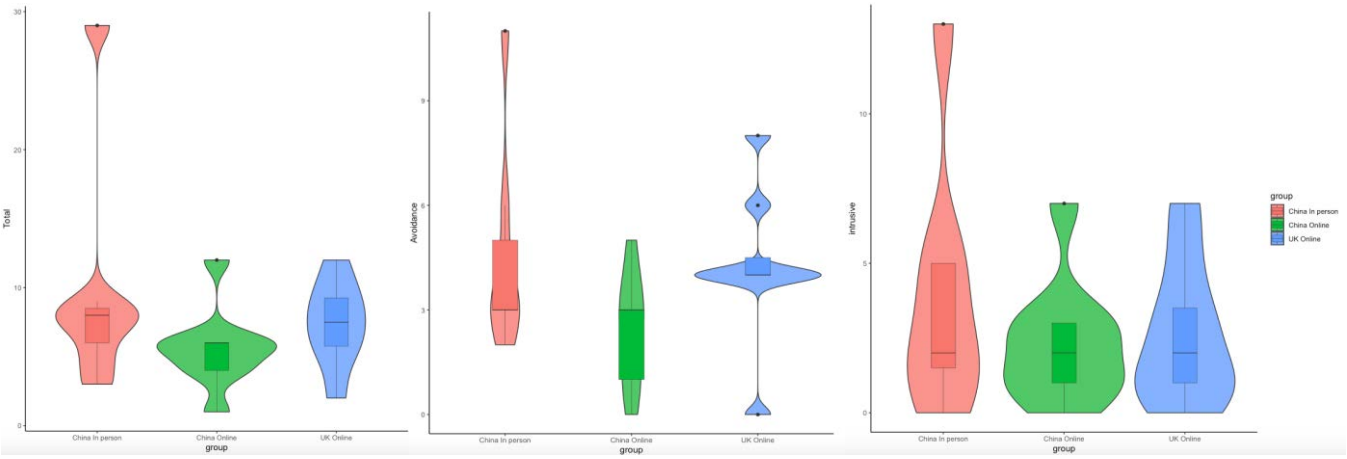

Figure 19. *Total, Intrusive and Avoidance score of IES-R from day 0 among groups (China in person, China online, UK online).*

IES-R (scores from day 1 to day 7 subtracted by day 0

From the result of IES-R original score, we found that there are no differences among experimental groups (UK in person; UK online; China in person), control groups (UK online; China online; China in person). There is also no difference between experimental and control groups in China in person / UK online. However, there is a difference between experimental group and control group in China in person on day 0 after post-intervention in a short period, which might be due to individual differences. Then, it is interesting to consider the score on day 0 as a baseline and compare the scores from day 1 to day 7 to evaluate the changes in symptoms in a relatively long term.

Experimental effect in China in person and UK online group

China in person

From two-way mixed ANOVA, we found there are group differences in total ($F(1,102) = 4.826$, $\eta^2 = 0.221$, $sig._{total} = 0.042$), avoidance ($F(1,102) = 20.904$, $\eta^2 = 0.551$, $sig._{avoidance} = 0.001$). There is a day difference in intrusive ($F(6,102) = 5.731$, $\eta^2 = 0.072$, $sig._{intrusive} = 0.001$). There are also day*group differences in avoidance ($F(6,102) = 2.521$, $\eta^2 = 0.034$, $sig._{avoidance} = 0.049$), and intrusive($F(6,102) = 3.994$, $\eta^2 = 0.050$, $sig._{intrusive} = 0.009$). From Bayesian two-way mixed ANOVA, there is a group difference in avoidance score ($BF._{incl\text{-}avoidance} = 277.488$). There are also day differences in intrusive ($BF._{incl\text{-}intrusive} = 27559.933$) and avoidance ($BF._{incl\text{-}avoidance} = 11.260$). Therefore, the experimental group decreased more than the control group in total and avoidance score.

Table 15

Two-way mixed ANOVA for IES-R score in total, intrusive, avoidance division that subtracted from day 0 between experimental and control group (China in person).

	Multivariate test	Mauchly's test	Within-subject effect (with effect size)		Between-subject effect (with effect size)
			day	Day*group	group
Different_T	0.552	0.001*	0.096 (0.040)	0.213 (0.026)	0.042* (0.221)
Different_A	0.364	0.001*	0.122 (0.026)	0.049* (0.034)	0.001* (0.551)
Different_I	0.546	0.005*	0.001* (0.072)	0.009* (0.050)	0.639 (0.015)

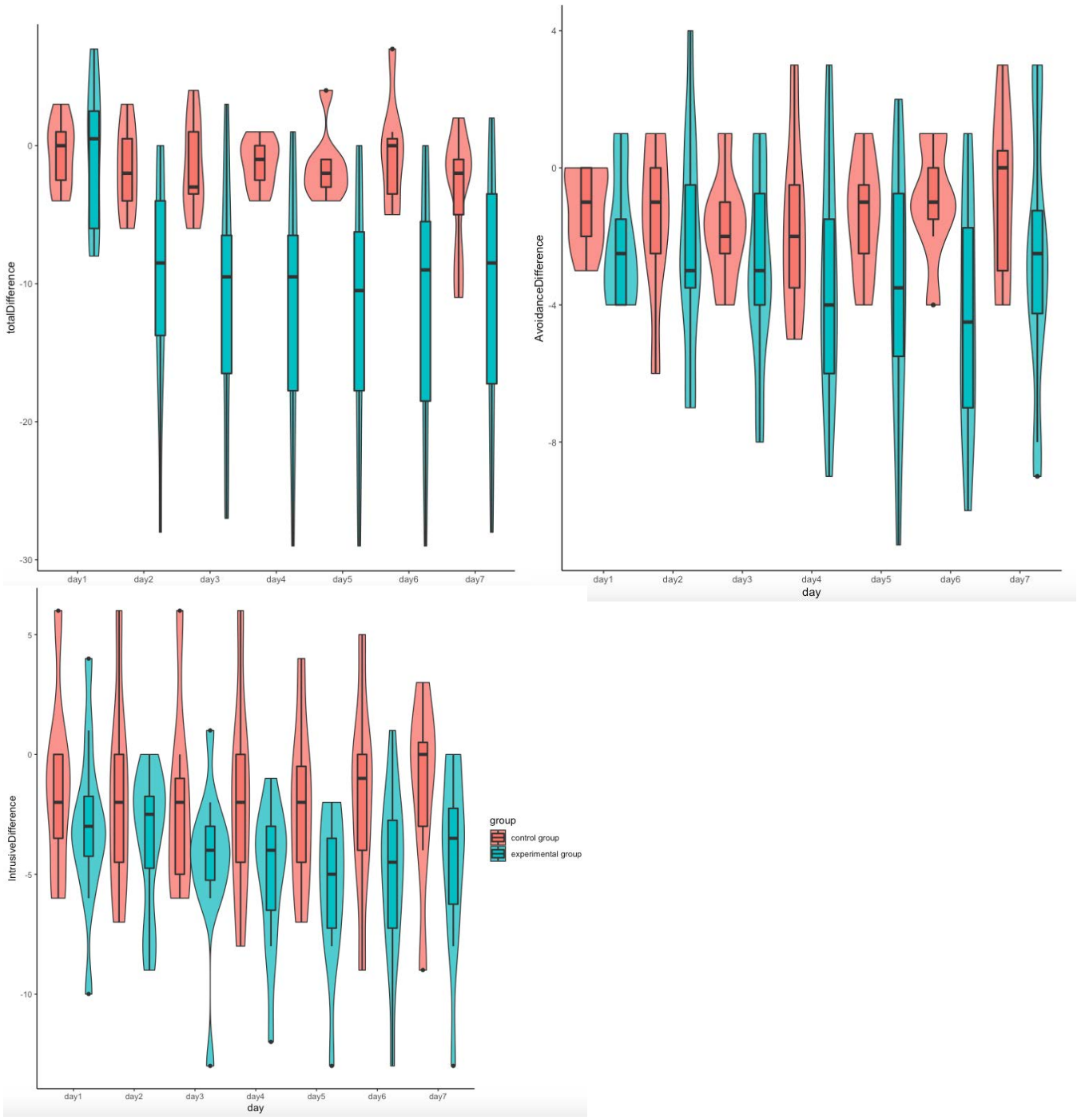

Figure 20. *Total, Avoidance, and Intrusive score of IES-R from day 1 to day 7 subtracted from day 0 between experimental and control group (China in person).*

UK online

From two-way mixed ANOVA, we found there is group difference in total (F (1,102) =4.627, η^2=0.198, $sig._{total}$ =0.044). From Bayesian ANOVA, there is no difference between experimental and control groups. Therefore, the experimental group might decrease more than the control group in total score.

Table 16

Two-way mixed ANOVA for IES-R score in total, intrusive, avoidance division that subtracted from day 0 between experimental and control group (UK online).

	Multivariate test	Mauchly's test	Within-subject effect (with effect size)		Between-subject effect (with effect size)
			day	Day*group	group
Different_T	0.346	0.001*	0.078 (0.038)	0.328 (0.019)	0.044* (0.198)
Different_A	0.485	0.001*	0.429 (0.008)	0.086 (0.021)	0.391 (0.039)
Different_I	0.409	0.048*	0.429 (0.009)	0.086 (0.023)	0.142 (0.110)

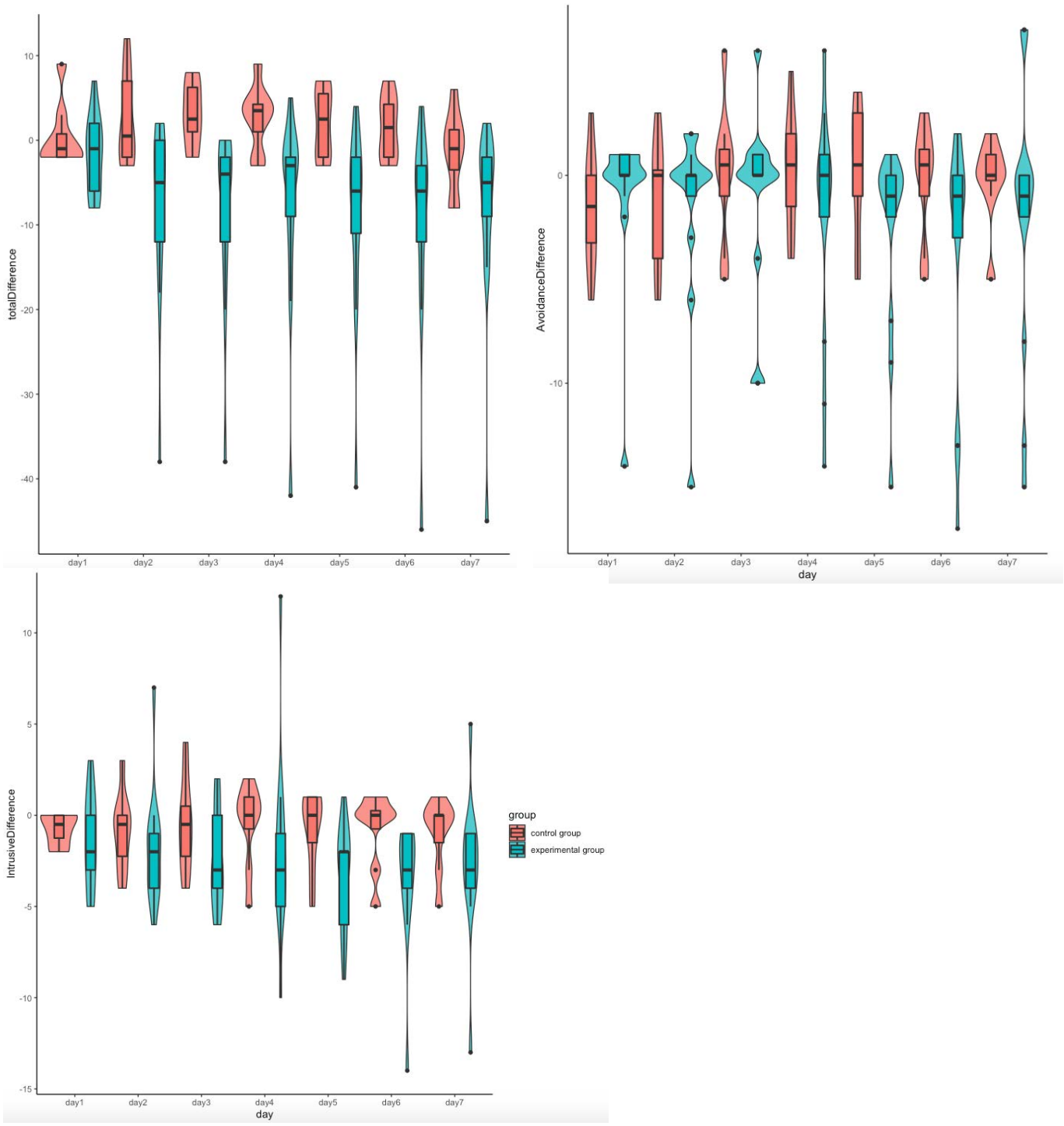

Figure 21. *Total, Avoidance, and Intrusive score of IES-R from day 1 to day 7 subtracted from day 0 between experimental and control group (UK online).*

Experimental group

From imputed data, there is a day difference in total (F (6,324) =7.764, η^2=0.37, $sig._{total}$ =0.012), interaction effect among group*day in total (F (6,324) =2.677, η^2=0.31, $sig._{total}$ =0.038), and group difference in total(F (2,39) =4.740, η^2=0.20, $sig._{total}$ =0.014). From multiple comparisons, UK in person decreased significantly than China in person (Sig. = 0.033) and UK online (Sig.= 0.024) in total score. From two-way mixed ANOVA with original data, we found there are day difference in total (F (6,246) = 2.746, η^2=0.011, $sig._{total}$ =0.034), avoidance score (F (6,246) = 4.020, η^2=0.018, $sig._{avoidance}$ =0.007) intrusive score (F (6,246) = 4.157, η^2=0.024, $sig._{intrusive}$ =0.008). Moreover, there is a group difference in total score (F (2,30) = 7.375, η^2=0.330, $sig._{total}$=0.002) and intrusive score (F (2,30) = 5.601, η^2=0.272, $sig._{intrusive}$=0.009). From multiple comparisons, UK in person decreased significantly than China in person (Sig. = 0.004) and UK online (Sig.= 0.005) in total score. Moreover, UK in person also decreased significantly more than UK online in intrusive score (Sig.= 0.006). From Bayesian ANOVA, there is a group difference in total score ($BF._{incl\text{-}total}$ = 11.738), this is contributed by the difference between UK in person and UK online ($BF._{10,u}$= 4.889*10^9), but also UK in person and China in person ($BF._{10,u}$= 1.320*10^9). Moreover, there is a day difference in intrusive ($BF._{incl\text{-}intrusive}$ = 94.079) and avoidance ($BF._{incl\text{-}avoidance}$ = 62.643). From the result, it is clear that UK in person decreased more than other two groups (UK online; China in person) in total score, and UK in person possibly decreased more than UK online in intrusive score.

Table 17

Two-way mixed ANOVA for IES-R score in total, intrusive, avoidance division that subtracted from day 0 among groups (China in person, UK in person, UK online).

	Multivariate test		Mauchly's test		Within-subject effect				Between-subject effect (with effect size)	
					day		Day*group		group	
	original	imputation	original	imputation	original	imputation	original	imputation	original	imputation
total	0.054	0.000*	0.001*	0.000*	0.034* (0.011)	0.012* (0.37)	0.204 (0.011)	0.038* (0.31)	0.002* (0.330)	0.014* (0.20)
intrusive	0.108	0.112	0.001*	0.000*	0.008* (0.024)	0.198 (0.16)	0.984 (0.004)	0.851 (0.13)	0.009* (0.272)	0.062 (0.16)
avoidance	0.179	0.004	0.001*	0.000*	0.007* (0.018)	0.335 (0.11)	0.731 (0.005)	0.944 (0.07)	0.053 (0.178)	0.237 (0.07)

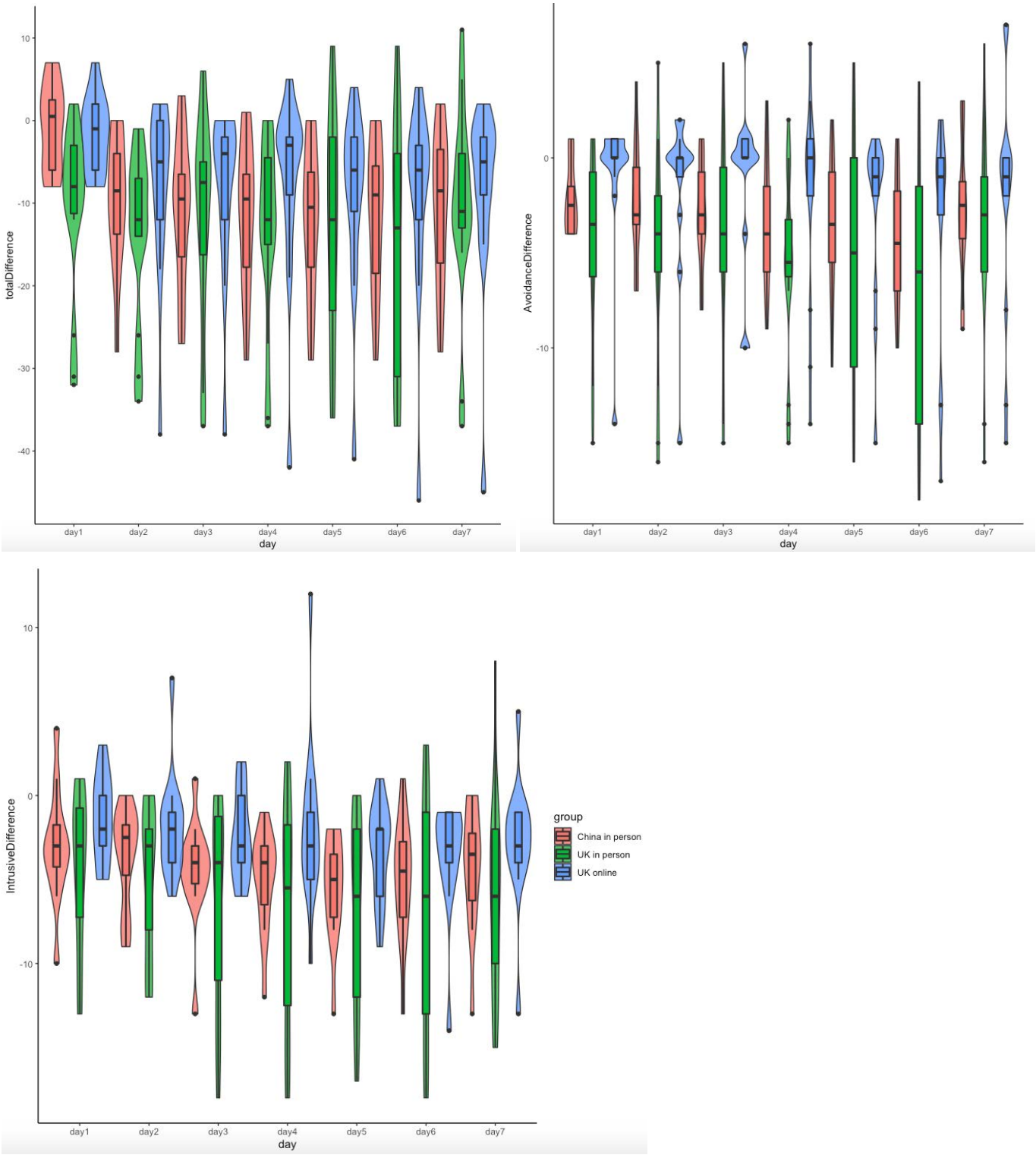

Figure 22. *Total, Avoidance, and Intrusive score of IES-R from day 1 to day 7 subtracted from day 0 among groups (China in person, UK in person, UK online).*

Control group

From two-way mixed ANOVA, we found there is a significant difference in total score (F (2,21) =5.355, η^2=0.338, sig. =0.013). Furthermore, this is contributed by the difference between China online group and UK online group, where UK online group decreased significantly more than China online group (sig. =0.01). From Bayesian two-way mixed ANOVA, we did not find any significant difference in day and group difference. For day*group effect, there is a difference in total (BF. $_{\text{incl-total}}$ = 150.244) and avoidance (BF. $_{\text{incl-avoidance}}$ = 19.583). Therefore, it is possible that the UK online group decreased more than the China online group.

Table 18

Two-way mixed ANOVA for IES-R score in total, intrusive, avoidance division that subtracted from day 0 among groups (China in person, China online, UK online).

	Multivariate test	Mauchly's test	Within-subject effect (with effect size)		Between-subject effect (with effect size)
			day	Day*group	group
Difference_T	0.481	0.010*	0.112 (0.025)	0.062 (0.052)	0.013* (0.338)
difference_A	0.287	0.017*	0.996 (0.001)	0.015 (0.068)	0.057 (0.27)
Difference_I	0.206	0.001*	0.075 (.015)	0.186 (0.019)	0.736 (0.029)

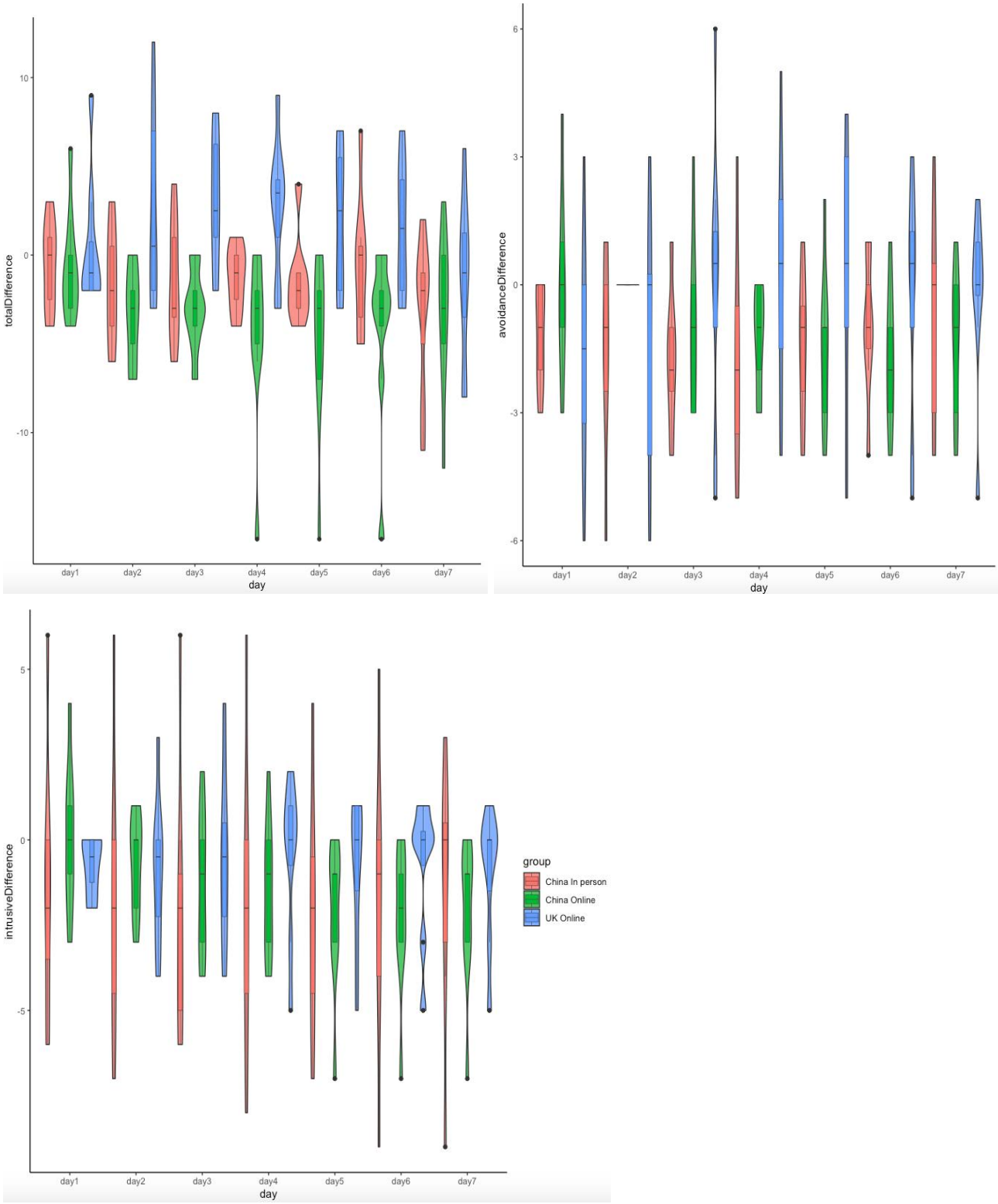

Figure 23. *Total, Avoidance, and Intrusive score of IES-R from day 1 to day 7 subtracted from day 0 among groups (China in person, China online, UK online).*

Discussion

In this experiment, we missed data from China online experimental group and UK in person control group. Thus, we did not have a complete dataset to compare the type (in person vs online) and nation (China vs UK). Then we checked our results for the following points. First, we transferred the experiment successfully (especially online) by comparing the control groups. Second, we tested the validity of memory training in online and Chinese by comparing the experimental groups with control groups in China in person, and also both groups in the UK online. We found there is a possibility that this memory training is valid for both Chinese and British. Moreover, participants in the UK reduced their PTSD-like memory quicker than participants In China, and Participants who attend this experiment online might reduce their PTSD-like memory slower than people who attend it in person. Table 19 summarised the significant results for IES-R scores among different groups.

Table 19

The significant difference among different groups in IES-R on day 0, IES-R that is different from day 0.

		IES-R on day 0	IES-R that different from day 0	
Group 1	Group 2	Total	Total	Intrusive
China in person (Experimental group)	China in person (Control group)	Group 1 scores > Group 2 scores	Group 1 reduction > Group 2 reduction	Group 1 reduction > Group 2 reduction
UK online (Experimental group)	UK online (Control group)		Group 1 reduction > Group 2 reduction	
UK in person (Experimental group)	China in person (Experimental group)		Group 1 reduction > Group 2 reduction	
	UK online (Experimental group)		Group 1 reduction > Group 2 reduction	Group 1 reduction > Group 2 reduction
China online (Control group)	UK online (Control group)		Group 1 reduction < Group 2 reduction	
China online (Control group)	China in person (Control group)	No difference	No difference	No difference

When we compared control groups and experimental groups in the UK online and China in person. There is modest evidence suggesting that the experimental group decreased PTSD-like symptoms more than the control group. In other words, eye movement with counterconditioning might reduce trauma-like symptoms regardless of the culture difference

and can be delivered online. First, targeting memory itself is a good strategy for early intervention and can be highly adapted in different cultural environments. From Roberts and his colleagues' meta-analysis in 2019, they found that focus on trauma itself is effective for early intervention for symptomatic individuals. Moreover, some psychological therapies such as Cognitive Behavioural Therapy faced the challenge about conceptualising biopsychological models or mental health in different cultures (Soklaridis et al, 2020). However, eye movement + counterconditioning does not need individuals to understand these concepts, which can enhance the cultural appropriateness. From an online perspective, this training provides a unique format for internet-based training. From Simon and her colleagues' research about internet-based therapy in 2021, structured format of intervention can be important to deliver on the internet. This is also the advantage of eye movement + counterconditioning training, where individuals can receive clear instructions and self-help friendly procedures to avoid confusion. Thus, this training can be quite flexible and have potential to become an internet-based early intervention when we face challenging global situations such as pandemic.

However, there are differences among experimental groups. From the imputed dataset, there are day differences in total and intrusive score in the experimental group. Moreover, UK participants who attended experiment in person decreased more than Chinese participants who attended experiment in person and UK participants who attended experiment online in total score. The results in Bayesian statistics support that there is a group difference in total score that is different from day 0, and all day-differences in IES-R. For the control group, UK participants who attended experiment online decreased more than Chinese participants who attended experiment online in total score. Moreover, there is no difference between online and in person Chinese participants.

From the results, we ensured that this experiment was transferred successfully online. This is due to no group difference in IES-R score on day 0. Therefore, participants who participated in experiments online received precise instructions and the memory training as well as participants who attended experiments in the lab. We observed that both experimental groups in experiment 2 (China in person and UK online) reduced PTSD-like symptoms quicker than the control groups, which replicates the same effect in experiment 1 (UK in person). However, we did not replicate these results by Bayesian ANOVA. Therefore, there is a possibility that the memory training (eye movement + counterconditioning) for a different culture (China) and type (online) is as effective as the one in the UK in person group. However, the UK online

experimental group decreased least in IES-R score and received least effect from eye movement + counterconditioning among all experimental groups (UK online; UK in person; China in person). Then, there is one question floating to the surface: does culture (China vs UK) or type (online vs in person) play an important role in eye movement + counterconditioning?

From the culture perspective, participants in the UK reduced PTSD-like symptoms quicker than participants in China.When we combine different methods together, UK in person group decreased more than China in person group in total score, and this is confirmed by traditional and Bayesian ANOVA without violating the variance homogeneity. In addition, there is no difference in the original dataset about all the scores on day 0. Thus, the difference did not appear immediately but over a week. Therefore, participants perceived the war video clips at the same level, however, Chinese participants recovered less than UK participants from the war-video clips.

First, Chinese participants might process or integrate negative emotional memories harder than UK participants, according to their self-concepts that are influenced by culture. Furthermore, this difference can already exist when participants integrated the war video into their autobiographical memories without memory training. From control groups, we can notice that China online decreased less than UK online in total score, and there was no difference between China online and China in person. Therefore, participants from the UK might recover faster from trauma-like memory than Chinese participants without any intervention, which is consistent with previous research about autobiographical memory in different cultures (Nqweni & Van Rooyen, 2012; Jobson et al, 2014). From Self-Memory System model (SMS), goals (the working self) can encode and integrate memories into an autobiographical knowledge base, which is a hierarchically set of memories from general summaries of lifetime period at the top and increasingly details of individual events at the bottom (Jobson et al, 2014). SMS proposes that trauma can be a threat to the working self, and therefore it is hard to adapt into the autobiographical knowledge base. This is also similar to Nqweni and Van Rooyen's theory in 2012, where core schemas present the understanding of self, the world, and others. When the core schema or previously held belief is inconsistent with maladaptive memory processing, these memories would become intrusive. To reduce the PTSD-like symptom, it is important to reduce the inconsistencies between the trauma and self-coherence (Jobson et al, 2014). Specifically, culture has a great impact on self-concept through different social

orientations, beliefs, and values. As we mentioned in the introduction before, western cultures tend to conceptualize the self-concept as independent and autonomous, where eastern cultures tend to be fitness, and interdependent (Markus & Kitayama, 1991). In this experiment, the war video clips are from the movie Hacksaw Ridge, which describes one medical soldier solely saving other soldiers. This video is related to independent self-concept rather than interdependent one. Therefore, Chinese participants might have felt more inconsistent with their autobiographical self and harder to integrate into their memories. As a result, Chinese participants recovered less from war videos and decreased less in IES-R scores.

Second, Chinese participants might receive less benefit from eye movement and counterconditioning training due to the difference in perceiving positive emotional stimuli. The cognitive strategies we mentioned in the introduction are mainly about neutral stimuli. In these strategies, individualistic cultures prefer use of contrast and separation and collectivistic cultures prefer assimilation and connection in perception strategies (Oyserman, Sorensen, Reber, & Chen, 2009). However, when individuals face tasks with emotional stimuli, their attention and reaction can be different from neutral stimuli. For instance, our humour video clips are designed for individualism culture. More than 80% of humour video clips describe humour moments without relationships involved in. Researchers found that individual cue conditions produced more-intense positive emotional reactivity for European Americans than for Asian Americans (Chentsova-Dutton & Tsai, 2010). Thus, Chinese participants might receive fewer positive stimuli from humour videos, which will generate less prediction error than UK participants. Therefore, they might have benefited less from counterconditioning training, and decreased less in IES-R score.

Third, Chinese participants might be less sensitive about high-arousal emotional memories. Affective tasks or stimuli often have the advantages in cognitive presentation, based on their privileged processing status (Reeck & Egner, 2015). From Han and Ma's review in 2014, East Asian cultures are linked with increased lateral frontal activity that aims for low-arousal emotional states (like calm or peace). In contrast, western cultures are linked with increased Dorsal anterior cingulate cortex and insula, which support high-arousal emotional states (like happiness or anger). Therefore, when participants face high-arousal emotional states, Chinese participants may experience less emotional arousal and be involved in the tasks. Then, Chinese participants reduced less in negative valence from counterconditioning, and led to less

enhanced long-term memory (Talmi, 2013). As a result, they have less changes in trauma-like symptoms than participants in the UK.

From the type perspective, participants who did experiment online recovered less from trauma-like memory than participants who did experiment in person. From the results, UK participants attending experiments in person decreased more than UK participants attending experiments online in total IES-R score and intrusive score. Unfortunately, we did not have enough measurements to explore the reason behind it. One possible reason can be participants who did experiments online were in a stressful environment. In this experiment, participants in an online group attended the experiments in their own room, while participants in the in-person group did it in the lab. Then, participants in the online group watched the war video clips in a comfortable environment which might have introduced them more stress due to the incongruence between the surrounding environment and war video clips. As a result, they might have higher intrusive scores with stress conditions in a relatively long term. This is consistent with Cheung's study in 2015, where participants had higher intrusive scores with stress conditions after four days. Researchers found that increasing stress can contribute to intrusive memories, which might be due to the increased glucocorticoid release at the time of the unstable memory that leads to poor coherence and contextualization (Cheung, Garber & Bryant, 2015). Moreover, these poor coherence and contextualization can bring a longer effect instead of immediate effect on participants. As a result, participants who received the memory training online were harder to contextualize their memories through a stressed environment, and therefore decreased their PTSD-like symptoms less than participants who did experiment in person. Nevertheless, we need further studies with stress measurements to check the replicability and observe whether stress is an important factor in home-based experiments.

Limitation

Due to covid-19 situation, the researcher failed to collect the China online group (both experimental and control group) and reduced the number of participants in each group. These bring several ignored limitations for this study.

First, due to the missing part (China online) of this design, it is impossible to conduct factors analysis about Nation * Type in ANOVA. Alternatively, it is plausible to compare the group difference, which however increased the change of Type I error.

Second, due to the limited participants, it has larger standard error with wider confidential level than large sample size (Hackshaw, 2008). As a result, this study is more likely to make type 1 error and the findings become imprecise.

Third, there are some pronounced outliers in this dataset. However, due to the limited sample size, there are some pronounced outliers in control groups, but the sample size of these groups is small. Hence, it is unlikely to delete the outliers which results in smaller sample size. However, winsorizing might not work here, as it is based on replacing the extreme value within the 5^{th} and 95^{th} percentile (Shete et al,2004). However, winsorization does not significantly reduce type 1 error for the variance components-based tests such as ANOVA for non-normal data (like this study) (Shete et al,2004). Nevertheless, this is the common problem for statistical approach in this study.

Due to the limited power in this study, any statistical approach has its own advantages and disadvantages here. Therefore, the methodological design and the number of participants play a crucial role in data analysis.

General discussion

Memory reconsolidation is not easy to achieve. In the beginning, we understand that eye movement does facilitate memory reconsolidation according to the results in both experiment one and experiment two, and counterconditioning can help participants to reduce PTSD-like symptoms. However, we only observe a relatively strong effect when we combine eye movement and counterconditioning together. As a result, it is necessary to explore which components reduce the PTSD-like symptoms, and which part of PTSD-like symptoms or memories was reduced, and what is the relationship between eye movement and counterconditioning in memory reconsolidation.

Memory reconsolidation can be universal. In experiment 2, we replicated the effect (eye movement + war + humour) in different cultures and types. However, we only compare the difference between fully memory reconsolidation condition (eye movement + counterconditioning) and control group, which has the same effect as experiment 1(UK in person). We did not add more groups in experiment 2 to replicate the insignificant effects in experiment 1, which includes the difference between eye movement + counterconditioning and

counterconditioning only, and also complete counterconditioning and incomplete counterconditioning with eye movement. Therefore, we still did not know whether eye movement can enhance counterconditioning significantly, and whether culture or type can affect eye movement or counterconditioning separately.

Moreover, when referring to episodic memory, especially trauma-like memory, it is interesting to consider cultural and affective factors. We failed to predict the result when we only considered cognitive strategies in non-affective tasks and self-concept in culture differences. However, we ignored several facts that might lead to different results. The Adaptive Information Processing (AIP) theory assumes that there is a direct neurobiological system that can naturally process life experience to its most adaptive outcome possible (Shapiro, Laliotis, 2011). If we consider cultural factors in individual experience, culture reinforced memory can integrate into an individual's experience more easily than culture incongruent information (DiNardo, 2018). Therefore, participants might not fully understand the humour clips and update their trauma-like memory (which is the war video).

For online and lab-based study, stress might be important in intrusive memories. Participants might experience less stress at home because they are in a comfortable and familiar environment without monitoring. There are some debates about whether stress is a distractor or facilitator in memory reconsolidation. However, a study using word lists as episodic memory supports that stress impairs memory reconsolidation (Dongaonkar et al, 2013), while studies used traumatic film paradigm support that stress will facilitate memory reconsolidation(which is the same in this experiment) (Cheung, Garber & Bryant, 2015; Schultebraucks et al, 2019). These differences might be due to the experiment itself, as the traumatic-film paradigm involves affective processing (trauma-like) but the word list does not. Therefore, it would be interesting to investigate if using Virtual Reality can blur the barrier between online and lab-based environments. Moreover, it is worth exploring whether a more immersive environment would enhance memory reconsolidation.

For clinical applications, early-stage intervention in PTSD can be crucial to recovery because traumatic experience would be more likely to develop as a traumatic episode when other negative and similar experiences present again (Shapiro, 2012). Furthermore, this study used traumatic-like memory instead of autobiographical memory, which can be good evidence to demonstrate the effectiveness of eye movement and counterconditioning in early intervention

for post-traumatic stress disorder. Then, eye movement and counterconditioning can diminish individuals' traumatic experience before another negative event happens again. As a result, individuals are less likely to suffer from trauma and cognitive impairment.

Furthermore, it would be also important to explore the mechanism of eye movement in memory reconsolidation. There is a theory against working memory theory called interhemispheric interaction, which believes that eye movement can enhance memory retrieval, rather than memory blurring. Studies have found that free recall or recognition depends on the communication between the cerebral hemispheres, which can be increased by eye movement (Christman & Propper, 2001). Unfortunately, more and more experiments disproved this theory by using various experimental materials (such as emotional words and old autobiographical memories that took over two weeks or) with electroencephalograms (EEG). They did not find that memory recall between horizontal and vertical eye movement were different, and there was no signal during experiments to show hemispheric interaction between left and right hemispheres (Samara et al,2011; van den Hout et al, 2014). Moreover, both horizontal eye movement and vertical eye movement reduced memory vividness and emotionality when participants recalled unpleasant memories (Gunter & Bodner, 2008). However, more evidence is still needed to support the working memory hypothesis not only from behaviour results but also from brain mechanism. Unfortunately, there is insufficient evidence to discuss how eye movement facilitates memory destabilisation or block memory updating. Previous EEG studies in memory reconsolidation were either focused on prediction error (Fernández, Boccia & Pedreira, 2016) or correlation with sleeping (Sharma, Sahota & Thakkar, 2020). Thus, it will be interesting to explore the signals in the brain by EEG, which could improve the efficiency of eye movement by understanding what the role eye movement plays in memory reconsolidation.

About statistics

Bayesian statistics

For the IES-R original score, one-way repeated ANOVA and Bayesian one-way repeated ANOVA held completely different results on the IES-R original score when Bayesian confirmed between-subject effects. It is hard to determine if IES-R scores were significantly different among groups. The reason why two tools have different results might be explained by the different prior distributions used by these two statistical tools. The prior distribution is

Gaussian distribution in one-way repeated ANOVA while Cauchy Distribution (that is similar to Gaussian distribution but has a taller peak with slower decay in tails) is applied to Bayesian by JASP (Marsman & Wagenmakers, 2017). Moreover, the probability that H0 and H1 are true is adjusted in Bayesian, which can transfer into

$$p(data) = \frac{p(H_0) \times p(H_0)}{p(data)} (7)$$

and

$$p(data) = \frac{p(H_1) \times p(H_1)}{p(data)} (8)$$

(Marsland, 2014). Therefore, the sum of probabilities that H0 and H1 are true is not equal to 1 as traditional statistics assumes. The way that Bayesian analysis in determining whether H0 or H1 are true or not is also different from traditional analysis. According to the suggestions that Wagenmakers and his colleagues gave in 2017, BF10 > 10 was considered as strong evidence supporting H1. From one-sample Kolmogorov-Smirnov test, we can notice that distributions in IES-R were quite hard to determine, therefore the result from Bayesian can be more reliable.

Even though most of the results are different between traditional one-way repeated ANOVA and Bayesian one-way repeated ANOVA, it is noticeable that these two statistical analyses tend to have the same results when datasets are close to normal distribution. Therefore, when the dataset returns to normal distribution, One-way ANOVA would be as powerful as Bayesian One-way ANOVA. However, the main problem is that datasets would not follow normal distribution all the time. Therefore, having more flexible standards about significant levels seems to be more accurate than p value. Nevertheless, Bayesian analysis still faces the problem of prior distribution for post probability when public bias would let more successful experiments get published (Hu et al, 2018). As a result, it might be a good idea to use both of them to analyse a dataset.

Imputation method

From experiment one, imputation and original datasets have different results in group difference about some IES-R scores. This inconsistency might question the robustness of the findings. However, we need to consider carefully how the original dataset was analyzed by ANOVA and how the dataset was imputed.

First, participants with missing data would be deleted from repeated measurement ANOVA due to the nature of its calculation. Therefore, participants with missing data were excluded

and this can potentially create a bias on study. For example, participants with high scores in IES-R might not want to fill the questionnaires for one or two days due to their avoidance. Also, participants with low IES-R scores might simply forgot to fill in the questionnaires. However, excluding these data has the potential to impact the significant level.

Second, this study used “mice" package from R, which based on a Fully Conditional Specification (FCS) implemented by Generates Multivariate Imputations by Chained Equations (MICE) as described in Van Buuren and Groothuis-Oudshoorn (2011), and it assumes that the value is missing at random. However, there is a possibility that some values might miss at random as some participants might be easier to forget to fill the questionnaires. Furthermore, this study lacks information to check whether the data miss at random or not.

Third, if all the values miss at random, then the difference between original and imputed analysis reflects that the finding is not robust. The imputed dataset filled in the missing value and would increase the number of participants in ANOVA. Then, it increased the power of this study, and should increase the likelihood of significant results if the original analysis showed significant results. However, imputed analysis showed non-significant results and the training effect goes away. Therefore, the finding that there are differences in IES-R score among different interventions needs further verification.

For future study, it is necessary to have more information about the missing value.

Conclusion

The results of this study support past findings that eye movement does facilitate memory reconsolidation and might contribute to memory destabilisation. Moreover, it also supports that counterconditioning with eye movement can integrate new information, which could be applied to early intervention for PTSD. In addition, this study also highlights the importance of culture congruence and context in psychological intervention. However, further investigations are needed to understand if eye movement blocks memory updating without prior memory destabilisation.

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